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An integrated mobile and web-based system for bus rapid transit (brt) in Dar es Salaam

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NM-AIST

AN INTEGRATED MOBILE AND WEB-BASED SYSTEM FOR BUS RAPID TRANSIT (BRT) IN DAR ES SALAAM

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A Dissertation Submitted in Partial Fulfillment of the Requirements for the Degree of Master's in Information and Communication Science and Engineering of the Nelson Mandela African Institution of Science and Technology

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ABSTRACT

The rapid population growth in Dar Es Salaam has prompted the demand of effective transport system in the city. This tremendous rise of population leads to a serious road traffic congestion, which brings a number of challenges into the city and other growing urban areas.

The city's local governments attempted various solutions to control the traffic congestions including building of other roads, expansion and extension of present roads, installation of traffic lights and other transportation infrastructures though they have not relieved the problem. The Government of Tanzania (GoT) supported the city's efforts by establishing the administrative organ called Dar Es Salaam Rapid Transit (DART) to administer the implementation of Bus Rapid Transit (BRT) system.

The government through DART has improved the public transport in the city. The BRT system provided direct benefits to passengers like minimal travelling time, improved reliability as compared to other public transport commonly known as *daladala* and accident reduction because BRT buses use their exclusive lanes.

Besides its advantages, the newly adopted transport system has brought some challenges to its customers. Among others are; a queue during ticket booking, shortage of smart cards, and inability to check and top-up balance using passengers' mobile phones.

Therefore, the study presents a software-based solution that will help passengers to check balance, send request by specifying station to board a bus and check or predict bus arrival time at any station.

DECLARATION

I, Reuben Alfred do hereby declare to the senate of the Nelson Mandela African Institution of Science and Technology that this dissertation is my own original work and that it has neither been submitted nor being currently submitted for degree award in any other institution.

Reuben Alfred _____ _____

Name and signature of the candidate **Date**

The above declaration is confirmed

Dr. Shubi F. Kaijage _____ _____

Name and signature of the supervisor **Date**

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CERTIFICATION

The undersigned certify that has read and found the dissertation acceptable by the Nelson Mandela African Institution of Science and Technology.

Dr. Shubi F. Kaijage _____

Name and signature of the supervisor **Date**

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DEDICATION

This dissertation is dedicated to my beloved daughter, Adelaide Reuben Mwakibinga.

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LIST OF ABBREVIATIONS AND SYMBOLS

ASP	Active Server Pages
AfDB	African Development Bank
APK	Android Package
BRT	Bus Rapid Transit
CSS	Cascading Style Sheet
CSV	Comma Separated Values
DART	Dar Es Salaam Rapid Transit
DFD	Data Flow Diagram
DSTV	Digital Satellite Television
DUCE	Dar Es Salaam University College of Education
ER	Entity Relationship
ESIA	Environmental and Social Impact Assessment
GIS	Geographic information system
GoT	Government of Tanzania
GPRS	General Packet Radio Service
GPS	Global Positioning System
HR	Human Resource
HTML	Hyper Text Markup Language
ICT	Information and Communication Technology
IDE	Integrated Development Environment
IoT	Internet of Things
IT	Information Technology
ITS	Intelligent Transportation Systems
NEMC	National Environment Management Council
PDA	Personal Digital Assistant
PHP	Hypertext Preprocessor
RAD	Rapid Application Programming
SMS	Short Message Service
SQL	Structured Query Language
SUMATRA	Surface and marine Transport Regulatory Authority
TANROADS	Tanzania National Roads Agency

TAZARA	Tanzania Zambia Railway
TRL	Tanzania Railway Limited
TZS	Tanzania Shilling
UDA	Usafiri Dar Es Salaam
UDART	Usafiri DART
UK	United Kingdom
UNISDR	United Nations International Strategy for Disaster Reduction
USD	United States Dollar
WWW	World Wide Web
XML	Extensible Markup Language
XTRAN	Excellence in Transport

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Transportation industry is among the main pillars of economic growth in Tanzania. Other sectors like agriculture, businesses, and mining to mention few, need transport to facilitate movements of goods, from rural areas to urban areas and the vice versa. The rapid population growth in Dar Es Salaam has increased the demand of effective transport system. In response, the Government of Tanzania (GoT) allocates a lot of fund into construction of transport infrastructures by building new roads and/or improving the existing ones. This is to aid rapid growth of other economic sectors by facilitating the communication and products movements between the producers and consumers (Kulkarni, Kalbande, Warrier & Gulrajani, 2012).

The massive movements of people into urban areas results into a serious road traffic congestions, which bring a number of challenges into big cities and rising urban areas. There are number of solutions proposed by transport practitioners to control the traffic congestions. Among others are building of new roads, expansion of existing roads, and installation of traffic lights. However, as congestion continues to increase, the conventional method of building more roads does not always work due to varying political, financial, and environmental reasons (Hawi, Okeyo & Kimwel, 2015; Rahane, 2014). Moreover, several countries which invested a lot in constructing road networks and infrastructures are currently facing a challenge of revitalizing their huge network and making the use of their existing road capacity before expanding further (Hamisi, Mwinyiwiwa, Mvungi & Mfinanga, 2018).

Local government authorities in Dar Es Salaam has taken various efforts to reduce the challenges of serious growing traffic jam in the city by building feeder roads, re-establishing commuter trains, and fixation of traffic lights (Mfinanga & Fungo, 2013). But these efforts seem to be futile due to fast increasing population.

To address these problems and find the lasting solution, the government of Tanzania planned to implement the Dar Rapid Transit Agency (DART) under the Prime Minister's Office, Regional Administration and Local Government through the Ministerial Advisory Board. Dar Rapid Transit Agency was formed as agency that would establish and operate Bus Rapid Transit (BRT) system in Dar Es Salaam city as an addition to the city efforts to provide good

quality, high capacity and efficient public transit service. The project has been planned to be implemented in six phases, and the first phase which is in operation runs from Kimara to Morocco, Kivukoni and Gerezani. It was expected that BRT buses would replace the current dominating public transport service called *daladala* along Morogoro road and therefore reduce traffic congestion and hence enable many people to arrive early in their workplaces (African Development Bank, 2015). In addition, DART aimed to create employment to citizens by inviting investors in the operations of BRT buses, fund management and fare collection companies. The private company which was commissioned to operate the project on behalf of DART is called Usafiri-DART (UDART) which is under Simon Group companies that own the city's public transport company called Usafiri Dar Es Salaam (UDA) by 51% of shares and also became the big shareholder of UDART, which is currently operating BRT system (Adam, 2018).

The commencing operations of BRT bus service in Dar Es Salaam became a relief to residents who used to spend hours to and from their work places. Among others, BRT has fastened services with time savings, cheapen means of transport communication, and provided reliable and comfortable services as compared to *daladala.* Furthermore, it is environmentally friendly because of low vehicle emissions and noise. Though the system has benefited the city dwellers, BRT bus passengers have also experienced challenges which may hinder some people to continue using BRT buses. These challenges are unreliable waiting time of buses in bus stations, queue in ticket booking, failure to check and top-up card balance via smart phones and failure to predict the next bus arrival time at specific station.

This study proposed and developed a solution to the existing challenges facing passengers as it suggests a software-based system that integrates android mobile application and web-based system. The developed system can enable passengers and UDART at large to; check card balance, send a request to board a bus at a particular station, mapping card details to a particular owner, and keeping and managing UDART information efficiently. Additionally, the study recommends other software modules that couldn't be fulfilled in this study to be implemented in future works.

1.2 Research Problem Statement

The public transport service provided by BRT buses in Dar Es Salaam experiences challenges such as unpredictable waiting time, long queue on ticket booking, overcrowding of people in buses and in stations or terminals, and inability to top-up and check card balance for those who use smart cards. Henceforth, some city residents may opts to use their private cars regardless of higher costs that on other hand causes serious traffic congestion in the city (Africa Development Bank, 2015).

The traffic congestion in Dar Es Salaam city has resulted into significant harmful impacts to the environment, economy and quality of life of individuals, families and whole of Dar Es Salaam community at large as it leads to an increase of transport costs and carbon dioxide emissions from vehicles because of increased idle time (Fernando, Gray & Kellner, 2013**).** Furthermore, it is projected that road traffics cost the state's economy up to 20% of annual profits in many business activities. Day-to-day losses due to traffic jam is estimated to be about USD 4 billion which is equivalent to TZS 1.44 trillion per annum in Dar Es Salaam alone (Mpogole & Msangi, 2016).

This study focused on examining on how a software technology can be used in improving BRT bus services in order to impress many people to commute with BRT buses. This has been achieved by proposing a mobile application integrated with web-based system that can provide an effective alternative to access buses' transit information such as passengers' card balance, bus arrival time and a request to board at any station as specified by passenger (Roy, Bandyopadhyay, Das, Batabyal & Pal, 2010).

1.3 Rationale of the Study

Normal people believe that improving transit systems only means construction of new infrastructures and expanding existing roads. But the upcoming of transportation depends not only in physical infrastructures, but also in the innovation of technology like software, traffic lights, and devices that gather, process and propagate information regarding the functioning of the transport infrastructures (Ezell, 2010). The thought-out system will provide the following contribution;

(i) To increase ability to forecast travel time with high accuracy
(ii) To reduce passengers' bus waiting time so as to arrive at working place on time

(iii) To help passengers being able to view and top-up card balance while at distant using their mobile phones.

(iv) Encouraging city residents to commute with BRT buses rather than their own cars or *daladala* which will help to minimize traffic congestion, air pollution and carbon dioxide emission.

1.4 Objectives

1.4.1 Main Objective

The main objective of this study is to develop an integrated android mobile and web-based system as a solution to the challenges facing passengers commuting with BRT.

1.4.2 Specific Objectives

The study was guide by the following specific objectives:

(i) To review current initiatives used by UDART for provision of buses' pre-board transit information and passengers' account balance in Dar Es Salaam.

(ii) To develop an integrated android mobile and web-based system for provision of BRT transit information.

(iii) To validate the developed integrated android mobile and web-based systems.

1.5 Research Questions

(i) What are the current systems or methods used by UDART to provide BRT buses' transit information to passengers?

(ii) What requirements are needed for developing an integrated android mobile and web-based system?

(iii) Does the developed system meet the users' specifications?

1.6 Significance of the Study

The study provides the conceptual design of database systems that can be used in the implementation of centralized database for storing transit information in public transport such as BRT buses and commuter trains. It also enlightens on how to employ the use of open source software in the development of mobile applications integrated with web-based systems to improve public transit performance in growing cities.

Moreover the study introduces a lucrative software-based solution that can be used by BRT buses passengers to check their online balance, predict bus arrival time and send request to board a bus at any specific station. On the other hand, the software can be used by UDART to improve the management of their records.

1.7 Delineation of the Study

The government of Tanzania established BRT system that is a cost-effective transport system in Dar Es Salaam to guarantee fast and systematic traffic flow in the city. The project was phased into six phases. The first phase along Morogoro road, BRT infrastructures has been already completed with financial support from the World Bank and the government of Tanzania.

To enable the construction of the second and third phase of BRT System in Dar Es Salaam, the DART Agency commissioned M/s Kyong Dong Engineering Co. Ltd of Korea in joint venture with M/s Ambicon Engineering Limited of Tanzania to deal with an Environmental and Social Impact Assessment (ESIA). Due to the fact that the ESIA has to be done by the firms registered by the National Environment Management Council (NEMC), the joint venture commissioned M/s Environmental BENCHMARK Consulting Engineers to assess the environmental and social impact of the project (African Development Bank Group, 2015).

Table 1: Phases of BRT Implementation in Dar Es Salaam

BRT Phases	**Road Corridor**	**Length (km)**
1st Phase	Morogoro, Kawawa North, Msimbazi Street, Kivukoni Front	20.9
2nd Phase	Kilwa, Kawawa South	19.3
3rd Phase	Uhuru Street, Nyerere, Bibi Titi and Azikiwe Street	23.6
4th Phase	Bagamoyo and Sam Nujoma	16.1
5th Phase	Mandela Road	27.6
6th Phase	Bagamoyo Road	27.6

Adopted from (African Development Bank, 2015)

CHAPTER TWO

LITERATURE REVIEW

2.1 Traffic Congestion

Traffic congestion is a situation which relates to a number of vehicles on the road which eventually leads to the hindrance of regular vehicle's motion and therefore necessitate some extra-time to get to the destinations (Shamsher & Abdullah, 2015). There are two kinds of traffic congestions. It can be recurring or non-recurring. Recurring traffic congestion appeared always in a certain time especially at peak hours, because it is when workers move to and from their homes to work places and therefore reduce road capacity. On the other hand, a non-recurring traffic congestion occurs due to unexpected and unusual event such as floods, works in roads, roads maintenance, or presidential convoy (Agyapong & Ojo, 2018) which suddenly reduces the road capacity. Generally, road capacity is the major cause of traffic jam, where the number of vehicles on roads becomes high than its capacity.

Traffic congestion phenomenon cannot be solved by applying physical road infrastructure construction only such as motorways, flyovers and expansion of road capacity. It is also important to develop technological systems for transport management that can be used to manage traffic situations such as traffic lights (Suvarna, Khandewale & Ghosalkar, 2013). Traffic control system helps to improve the traffic flow and hence reduce traffic clogging on roads.

2.2 Bus Rapid Transit (BRT)

Bus Rapid Transit is a public bus based transit system which consists of a corridor of dedicated lanes that provide reliable and comfortable service and minimal travel time. Through the provision of dedicated lanes and outstanding in customer service, BRT essentially follow the performance characteristics of a modern rail-based transit system at inexpensive costs (Cervero & Kang, 2011). The following are features but not limited to, which are available on most successful BRT systems in operation to date: exclusive lanes, pre-board fare collection, safe, comfortable and real time transit information displays and automatic vehicle location tracking technology. Nowadays, the concept of BRT is progressively being more adopted by many growing cities that are concerned with cost effective public transport solutions.

2.2.1 History of BRT

There were variable previous efforts in improving customers' transit experience. The first project for the implementation of the BRT by using bus technology took place in Curitiba (Brazil) in 1974 (Deng & Nelson, 2011). Nevertheless, there were other smaller-scale efforts preceded to Curitiba which helped to set up the plan including that of the United States in the early 1960s. At this era, high-occupancy and express service buses using contra flow lanes were built in the New York City. Similarly, projects took place in other states of the United States including the St. Louis (1959), Milwaukee (1970) and Washington DC (1955-1959) (Deng & Nelson, 2011).

2.2.2 Benefits of BRT

(i) Comfortability of Passengers

The comfortability of passengers commuting with BRT buses was observed to be high. The results of their study about the comfortability of passengers shows that 56% of the passengers are satisfied with the BRT service compared to *daladala* (Hamisi & Kombe, 2017). Furthermore, passengers are satisfied with the environment at bus terminals or stations. However, passengers were observed to be dissatisfied with the process of availing tickets especially during peak hours when high number of people is observed hence leading to a long queue causing unnecessary delays in stations or terminals. The plan to get rid of delays due to ticketing system is that UDART should provide more smart cards where a passenger is required to top-up balance instead of buying a ticket every time he or she wishes to travel.

Figure 1: BRT Buses in their Exclusive Lanes

(ii) Time Effeteness

The existence of BRT system has largely reduced the travelling time when compared to the *daladala*. Contrary to *daladala* that spent an average time of 60 to 80 minutes to travel from Ubungo to Kivukoni terminals, the BRT takes about 40 minutes to travel with BRT from Kimara to Kivukoni (Adam, 2018).

(iii) Road Traffic Accidents and Vehicles Crushes

In 2015 and 2016, a total of road accidents due to motorcycles commonly known as *bodaboda* in Dar Es Salaam were about 1222 (Tanzania Police Force, 2017). Following this frequency of road traffic accidents due to inattentive *bodaboda* and *daladala* drivers, the passengers consider to be more secured when travelling with BRT buses. This is because BRT buses use the exclusive lanes leading to low possibility of collision.

2.2.3 Influence of ICT on Improving BRT Operation

The modern BRT buses require more sophisticated methods in their operations. Challenges that passengers experience from commuting with BRT buses are due to reliance of manual procedures. For instance, queue during ticket booking can be resolved by replacement of

technology that can allow passengers to book a ticket at distant using mobile smart phones. Overcrowding in stations or terminals can be resolved by using mobile application that will help passengers to get real time transit information such as bus arrival time, location and speed of the buses. Knowing the bus arrival time may help passengers to arrive at station with assurance of time at which the bus has to arrive and hence avoid unnecessary long waiting of buses in bus terminals. The following are some technologies that can be used to develop applications which can be applied in management of public transports including BRT.

(i) Android Mobile Application

Android is an open source and improved Linux 2.6 kernel operating system built for mobile smart phones and tablet computers. Most of its drivers and libraries have been modified or newly designed to make Android Systems run faultlessly in many mobile devices (Singh, 2014). It was initially developed by Android Inc, later sold to Google. Android applications have been used to develop applications that are useful in management of transportation systems. Passengers in this modern era of internet-based smart phones and tablets need the provision of live transit information such as bus location and bus arrival time for a particular route. The choice of developing application for any purpose other than transport management system using Android operating systems is important since its community reach is maximum compared to others, in other words the number of clients using android based devices is greater compared to those using others like Symbian, iPhone and many more (Kulkarni, Kalbande, Warrier & Gulrajani, 2012). Example of transport management systems running in Android is Ride Systems GPS[3] which provides to passengers transit information such as real time bus location and next stop bus arrival time (Al Shammary & Saudagar, 2015).

(ii) Web-Based Systems

This is any information system which uses web-technologies to disseminate information to clients or other information systems. In other words, the web-based system is developed aiming at publishing and maintaining data based on hypertext principles or standards. Some Basic Web Standards includes;

HyperText Transfer Protocols (HTTP): The Hypertext Transfer Protocol is designed to enable communications between clients and servers. HTTP works as a request-response protocol between a client and server. Includes the following methods but not limited to:

- GET: Request for information requests.
- POST: Request to provide additional information in a request.
- PUT: Request to upload information to server.

HyperText Markup Language (HTML): HTML is a language used to write web pages on the World Wide Web (WWW).

The web-based system can also be used in disseminating transit information. The GPS, web GIS and GPRS technologies provide real time transmission of coordinates of the vehicle to the database server and lastly rendering on the web page. Vehicle location-based applications and tracking system existing in Tanzania and many other developing countries are mainly focusing on private cars (Otieno & Ngigi, 2012). Public transports have a slight consideration from vehicle-tracking companies. This might be due to the chaotic nature of common public transit system in growing cities and high investment cost of public transport management system. Nonetheless, the development of web-based GIS technologies and mobile-based GIS can be a virtuous solution for effective and efficient means of managing public transport in high populated cities (Al Shammary & Saudagar, 2015).

(iii) Intelligent Transportation Systems (ITS)

This is a group of technologies that can be used to improve transport management systems in private and public transit. ITS technologies include but not limited to computational technologies, floating cellular data, sensing technologies, automatic road enforcement, collision avoidance systems and dynamic traffic light sequence (Xiaolin, 2007).

2.3 Related Works

2.3.1 Ride Systems GPS3

Ride Systems Company was established in 2007 that deals with the delivery an effective GPS tracking solution. Among others, systems GPS^3 is a mobile application developed by the company which provides time to passengers about the next bus to arrive at the station, in other words it provides arrival time of the next bus. Additionally, the application offers an opportunity to the passengers to find bus stations (Al Shammary & Saudagar, 2015). It also provides the bus arrival times for the specific route. This application can run in Android and iPhone operating systems. However, the application lacks some features like passenger's ability to use smartcards.

2.3.2 The OneBusAway (OBA) System

The primary purpose of OneBusAway is to provide immediate bus arrival-time information of every next bus at a given station. OneBusAway offers a user-friendly interface and it provides several means to retrieve the data such as through a website, iPhone and Android applications. OneBusAway is an open source application so as to allow many other developers to improve the source code in collaboration with the development team. Also, the application has been open source to allow other transit practitioners to freely access the source code and use it (Edison, Ferris, Borning, Rutherford & Layton, 2011).

2.3.3 Excellence in Transport (XTraN) App

It's a public transport information system developed by a Portuguese company called Tecmic and it is applied in many public transport operators in Portugal and Brazil (Ferreira, Silva, Afonso & Afonso, 2017). The XTraN App is equipped on individual vehicle to maintain real time tracking of a public transportation vehicle activity by retrieving data from the vehicles such as its geographic location. It also delivers information about arrival time prediction, transport lines, schedules, stations, to mention but few to passengers through SMS, Web and electronic boards in some stations (Levita, Pereira & Leal, 2012). Getting this information in mobile devices encourages many passengers to commuting with the public transport vehicles.

2.3.4 Robin Hood Network

It's based in Nottingham, UK which integrates most public transport services and made easily available to customers into their mobile phones. The Robin Hood Network application enables passengers to check their smart cards balance, plan their journey or sending request to specify boarding stations, exploring bus stop, online top-up of card balance and many more. All these utilities are needed in our proposed prototype; however, they were developed purposefully to operate with public transport services within Nottingham, UK and therefore customization to fit the BRT system in our environment is a challenge

Therefore, the proposed prototype has been developed based on features available in Ride Systems GPS[3], OBA, Robin Hood Network and XTraN App to best fit our BRT system environments with three core functions; these are check and top-up card balance, bus arrival time and request to board a bus at any specified station.

CHAPTER THREE

MATERIALS AND METHODS

3.1 The Research Case Study Area

Several studies have been done in Dar Es Salaam concerning BRT service because it is the only city in the country that implements this modern transportation project. The aim of this study is to increase the satisfaction level of passengers who commute with BRT buses by developing a system that has to cut-off BRT challenges facing passengers as described in the introduction part. The adoption of such system can impress many citizens in Dar Es Salaam to travel with BRT buses with quality services at affordable prices.

Dar Es Salaam is the business hub city in Tanzania with a population of about 6.2 million people. The city is located in the Eastern part of Tanzania and it is bordered by the Indian Ocean on east and surrounded by the Coast region on its other sides. The city has five municipal councils namely Ilala, Kinondoni, Ubungo, Kigamboni and Temeke (United Nations Office for Disaster Risk Reduction, 2012). Like various other cities in developing countries, Dar Es Salaam suffers from insufficient transport infrastructures which lead into unreliable and unorganized traffic flow in the city.

The Surface and Marine Transport Regulatory Authority (SUMATRA) conducted a study in 2014 on demand and supply of public commuter buses in the city. According to the study, the total length of road networks in Dar Es Salaam is 2094.4 km. About 494.3 km (24%) are managed by Tanzania Roads National Agency (TANROADS) and 1600.1 km are under the municipals' control.

Dar Es Salaam residents are served by an approximately 6800 registered commuter buses. The licensed routes for public commuter buses is approximated to 362 **(**African Development Bank, 2015). The main public transport services that were available in Dar Es Salaam prior to BRT system were *daladala* and commuter train.

3.2.1 Commuter Buses

The *daladala* provides transport services to majority of people in the city. To ensure quality of services, the government through SUMATRA enacted some rules to *daladala* operators including the labelling colour of a given route to all *daladala* and providing clothing uniformity among drivers. These efforts have not yet being a solution since the transportation

Figure 2: Map of Dar Es Salaam

system face several challenges such as minimal control vehicles, absence of transport schedule, prolonged waiting at stations, unreliable of services during some hours in some areas particularly during peak hours, congestion of vehicles and congestion on roads (African Development Bank, 2015)**.**

3.2.2 Dar Es Salaam Commuting Rail Service

The commuter train transit service was launched and commenced its operations on 29 October, 2012. The service operates in two routes; the first route that is under Tanzania Railways Limited (TRL) covers 20 km between Ubungo-Maziwa and central railway station whereas the second one that is under Tanzania-Zambia Railway Authority (TAZARA), covers 25 km between Mwakanga (Pugu) and TAZARA station. The then minister of

transport and communication pronounced that a total of 6 billion TZS were spent on renovating the train carriage and railway infrastructures for TRL line while 800 million TZS were spent on repairing TAZARA lines. One-way ticket costs about 500 TZS and 100 TZS for primary and secondary students which are more affordable as compared to *daladala* that costs 500 TZS to 1000 TZS to non -students and 200 TZS for students depending on the boarding station. The commuter rail service is significant as a single trip collects large number of passengers. Average number of passengers using TAZARA line is about 9000 passengers per day while average number of passengers for TRL line is about 5000 passengers per day. However the service favours people living along the rail lines or close to end of service lines (Mihayo, 2013).

3.2 Development Approach

The methodology employed to design and develop a proposed system solution is a Rapid Application Development (RAD). It is an evolutionary development with time boxes or fixed time frames within which activities are done.

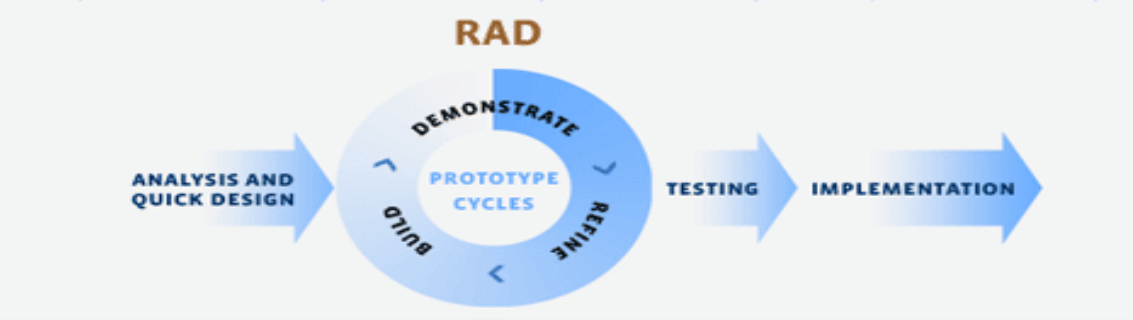

Figure 3: Rapid Application Development Stages

The selection of methodology was based on the fact that RAD takes short time and frequently involves the client on every steps of product development and hence assists to improve the client satisfaction because of several communications taking place and client is able to see the product progress. The Table 2 below shows the comparison of RAD against other methodologies of software development.

Table 2: Comparison of RAD versus Other Methodologies

Methodology	**Budget**	**Time**	**Functionality**
Waterfall	High	Long term	Static
Incremental	High	Short term	Static
Evolutionary	Low	Long term	Dynamic
Spiral	High	Long term	Dynamic
RAD	High	Short term	Dynamic
Extreme /Agile Development	Low	Short term	Dynamic/Static

Adopted from Dillma (2003)

3.2.1 Sample, Sample Size and Sampling Technique

The sample of the study comprised passengers found direct into bus stations and others from two companies namely Multichoice-Tanzania (DSTV) and Dar Es Salaam University College of Education (DUCE) employees who have experiences in commuting with BRT buses. About 250 questionnaires were distributed and 181 were returned, which is about 72% of all questionnaires. The questionnaires were distributed into three terminals; Kimara, Ubungo and Morocco. Moreover, 80 questionnaires were distributed at DUCE while 70 were distributed at DSTV. The remaining 100 were distributed into the selected terminals. The return of the filled questionnaires was as follows; 73 duly filled were collected from DUCE, 59 from DSTV and only 49 were returned from the three sampled terminals. A Simple random sampling technique was used. In this case each respondent was selected wholly by chance and each respondent was given an equal chance or probability of being involved.

3.2.2 Data Collection Methods

The data collection activity took place for about three weeks in April 2018. The methods used in this study were interview, questionnaires, and observations. Below is a brief description on how these methods were employed in gathering data from respondents.

(i) Interview

The structured interview with the guide questions was done involving UDART employees from HR, IT offices and two drivers. The objective was to understand the brief history of BRT in Tanzania, challenges they encounter, the level of technology they employ, number of BRT buses currently in operation and the average number of passengers they serve per day.

(ii) Questionnaire

Self-administered questionnaires designed with straight forward questions, close-ended questions**,** rating scale questions**,** and multiple choices questions. The objective was to identify the procedures and practices of activities, level of satisfaction of passengers to services provided and passengers' recommendation towards improving the service.

(iii) Observation

Observation was done from the UDART's office, terminals/stations and in the travelling buses. The aim was to know the bus scheduling process, average time each bus spends at every station, and technologies built in buses that are used to predict bus arrival time to next stations.

3.2.3 Data Analysis Methods

Qualitative and Quantitative data were gathered using questionnaires, interviews, and observations. The fully filled questionnaires were coded into electronic forms with respective responses using Google forms. After coding and filling all responses, then a CSV file was exported from Google form. The exported CSV file was imported into PyCharm software tool for data analysis using python programming language.

3.2.4 Requirement Analysis

Requirement analysis involves definition of user's needs before developing a new or modifying a product. These users' needs must be relevant, quantifiable and detailed. In this study, detailed user requirements were gathered, analyzed and finally led to formulation of functional and non-functional requirements.

(i) Functional Requirements

Functional requirement describe a particular function that can be performed by the expected system such as login, add user, delete etc.

Table 3: Functional Requirements

Requirement	Description
Add Staff, Add Departments, Add Vehicles, Add Routes, Add Stations, and Add Users	The System Administrator will register staff, departments, vehicles, routes, stations and users into the system.
Register Passenger	The data entry personnel will register passengers into the system together with their card numbers.
Login(Mobile Application)	The passenger is granted a functionality to enter into mobile application using his/her card number
Check balance	The functionality that enable a passenger to check his/her balance using mobile device
Choose boarding station	The functionality that enable a passenger to send request to the central system specifying a station at which he/she expect to board a BRT bus
View bus arrival time	The functionality that enable a passenger to view the bus arrival time at any station

(ii) Non-functional Requirements

Non-functional requirement defines any quality or behaviour which a system has.

Table 4: Non-Functional Requirements

Requirement	Description
Performance	➢ Updating and saving records shall be fast ➢ Login and logout operation shall respond quickly
Safety and security	➢ The user's login details are secured enough so that no one will be able to by-pass the system ➢ The system is secure enough to protect against Denial-Of-Service Attacks
Usability	➢ The system shall be easy to learn so that users know how to use the system on the first use

3.2.5 Architectural Design

This section explains and indicates the requirements needed to develop the proposed software-based solution for passengers commuting with the BRT buses in Dar Es Salaam. Tables 4 and 5 above present important requirements in developing the proposed solution; furthermore, this section expounds the overall design of the proposed solution by providing the conceptual framework of the system, use case diagram, data flow diagrams, database schema and entity relationship (ER) diagram.

(i) System Conceptual Framework

A conceptual framework is an analytical tool with several differences and contexts. It can be used in various types of works or projects where an overall picture of the end product is required. Strong and well-organized ideas in a conceptual framework can ease the overall process of developing something real. Based on the study findings, it was observed that there is a need to integrate two systems which are web-based and android mobile application where both have to store, retrieve and exchange data to and from the same centralized database.

Android Mobile Application: The mobile application integrated in the proposed system has been designed specifically to be used by passengers to interact with the central database. The passengers through mobile application interface are able to check balance, select and send request about boarding station and check bus arrival time.

Web-based System: A web-based system in the proposed solution is designed to be used by UDART administrative activities. The system keeps records of the organization to a centralized database such as staff, departments, vehicles, registered passengers, stations and route scheduling. Two users who are system administrator and data entry personnel are given different privileges to access the system. System administrator can almost access all menus however, the system can be customized to limit administrator from accessing any specified menu. Data entry personnel have been privileged to access few menus than administrator. Also, the system can be easily customized to add or reduce menus to be accessed by data entry personnel. Figure 4 bellow illustrates an overall conceptual framework and how external entities or users interact with the central database through the interfaces provided from mobile application and web-based system.

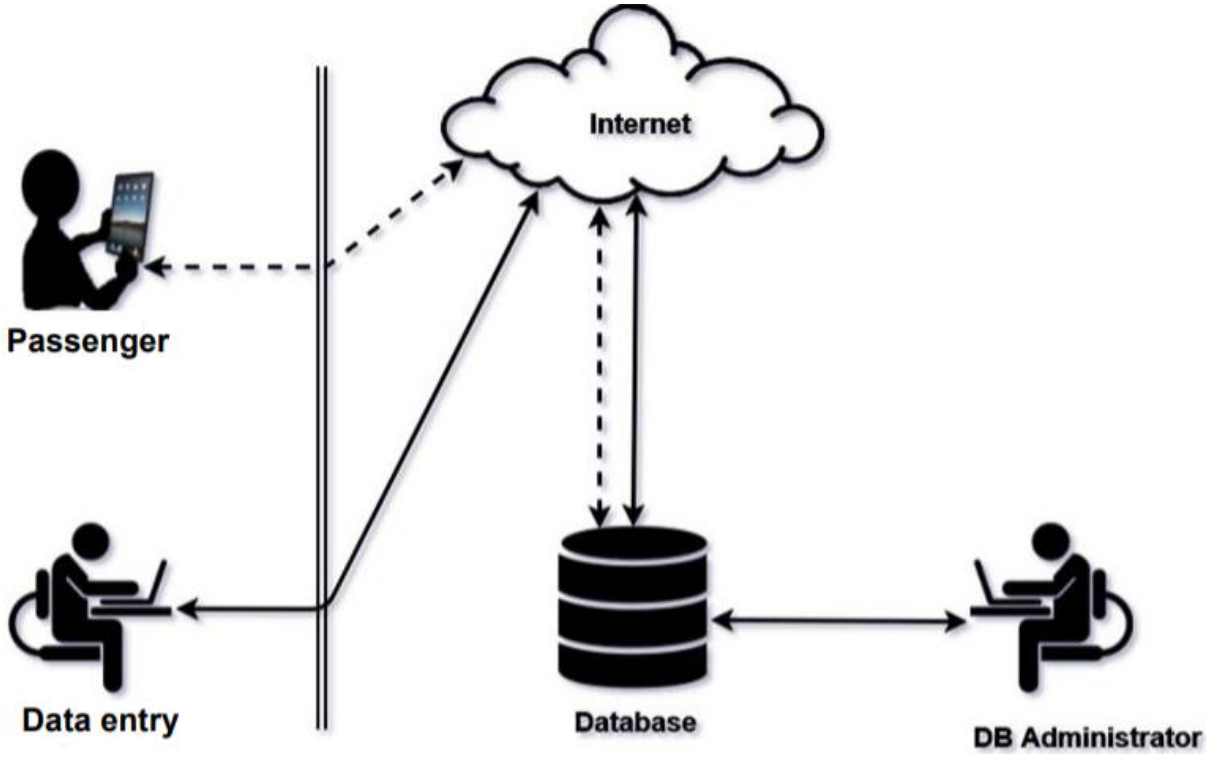

Figure 4: Conceptual Framework of the Proposed System

(ii) Context Diagram

A context diagram also known as DFD level 0 describes the relationship amongst the system and its environment (user and related system) showing the interaction of the existing entities with system process. It is the diagram that represents a high-level or top-level view of a system containing one process or process 0 that generalizes the overall function of the whole system in relation to external entities.

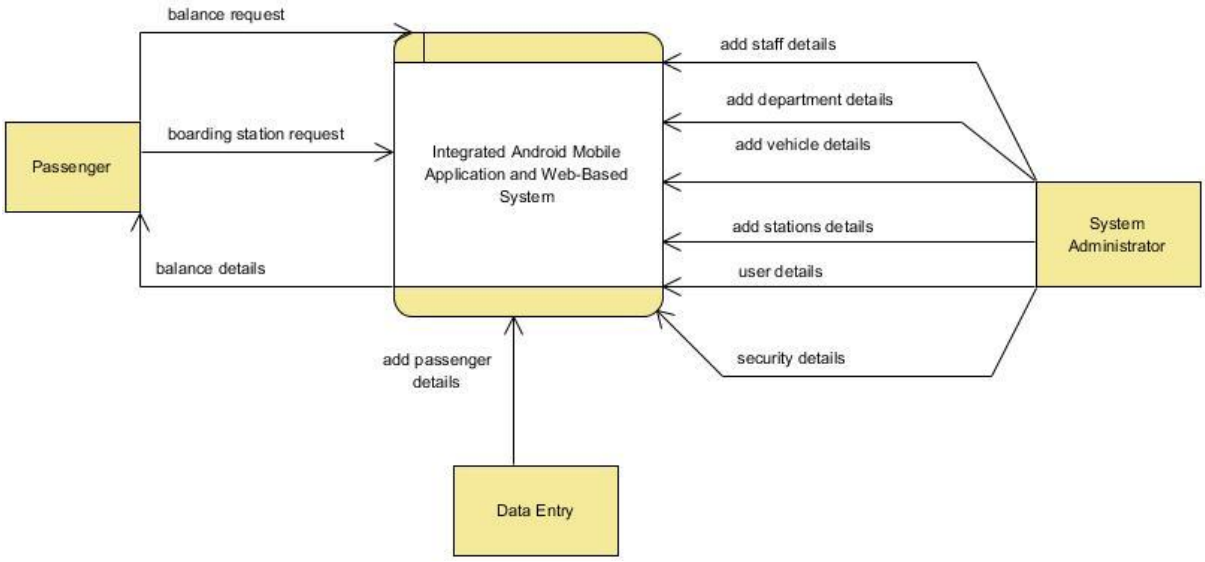

Figure 5: Contextual Diagram

(iii) Database Design

Database design involves the process of organizing data in accordance to a database model. It is a process of identifying entities, relationship of entities and attributes of all entities. The database designer determines what information to be stored and how the information should relate to each other. In other words, database design is the classification of data and establishing their interrelationships.

(iv) Entity Relationship (ER) Diagram

Entity Relationship diagram is a method used to document the entities and relationships during database design (Chen, 2002). It is a graphical representation of database system which represents the interrelationships among data that are expected to be stored into the within that system.

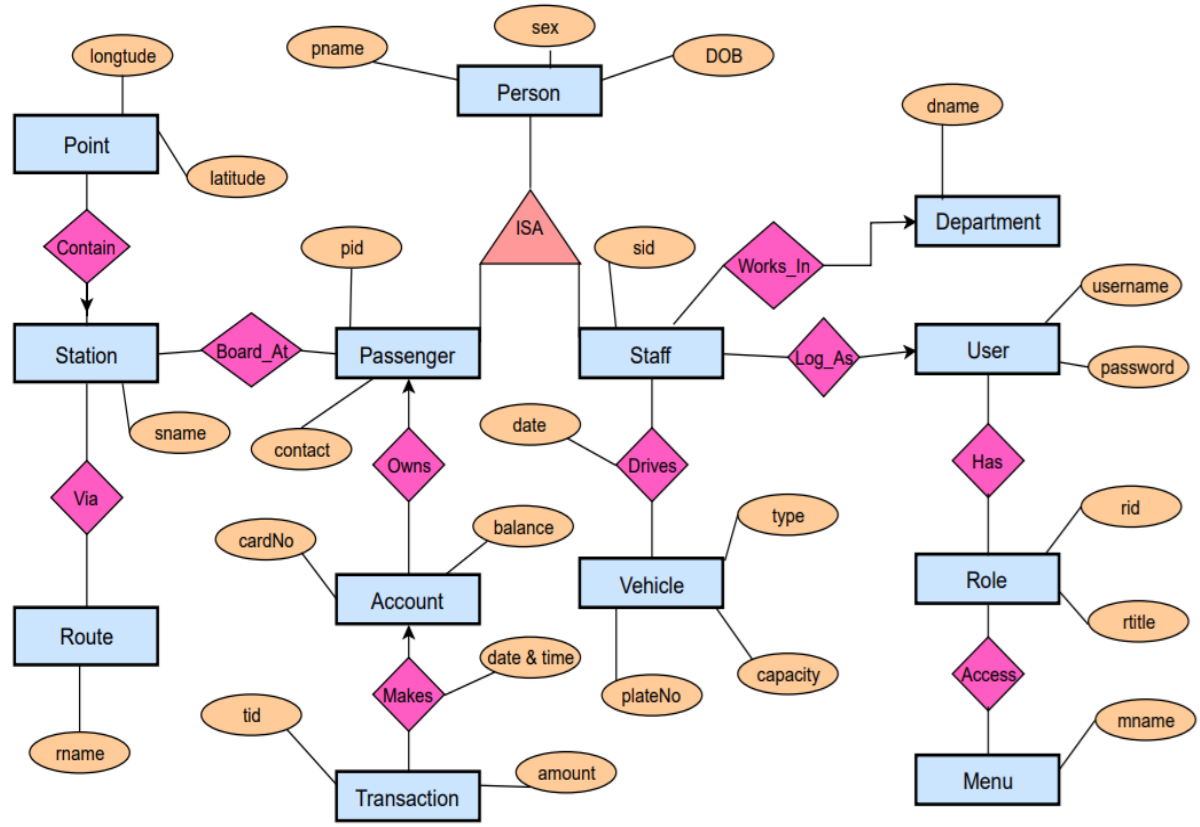

Figure 6: Entity Relationship Diagram

The entities extracted from the ER diagram in Fig. 6 are: Person, Passenger, Staff, Department, User, Role, Menu, Vehicle, Account, Transaction, Point, Station and Route. The relationships or associations among entities are: ISA or IS-A, Contain, Board_At, Works_In, Log_As, Via, Owns, Drivers, Has, Makes and Access.

The following are relational schemas of the ER Diagram in Fig. 6 above: Person (person_id, person_name, psex, DOB), Passenger (person_id, contact), Staff (staff_id), Department (dpt_name), User (user_name, password), Role (role_id, role_title), Menu (menu_name), Vehicle (plate_No, v_type, v_capacity), Account (cardNo, balance), Transaction (tid, amount), Point (longitude, latitude), Station (sname) and Route (route_name).

(v) Use Case Diagram

A Use Case Diagram depicts the interaction of users and the system. It describes what actions or processes a user can perform in the system. In Use Case Diagrams, Actions are called Use Cases or External Entities are called Actors.

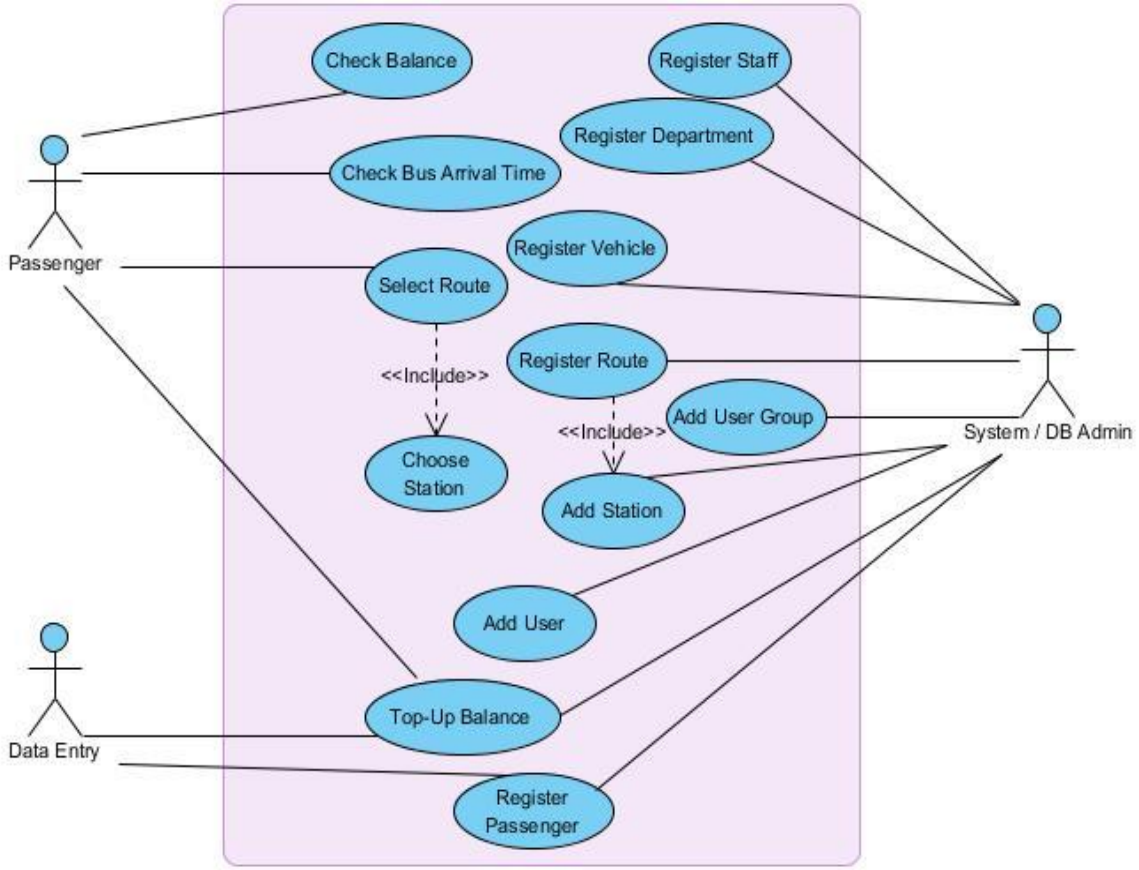

Figure 7: Use Case Diagram

Actors of the proposed system solution are Data entry personnel, Passenger, and System Administrator. The Use Cases: Check Balance, Check Bus Arrival Time, Select Route, Choose Station, Top-Up Balance, Register Passenger, Add User, Add Station, Add User Group, Register Route, Register Department, and Register Staff.

3.2.6 Development of the Proposed System

The survey indicated that many respondents recommended or were willing to provide them with the new technology that can enables to check their balance and bus arrival time. Consequently, the study developed a system which integrates an android mobile application and web-based system. There are two groups of users in the proposed system; first group are the passengers who interact with the central database through android mobile application and

the second one is the UDART administration (system administrator and data entry personnel) who interact with the central database through the web-based system. The selection of technologies to use in developing the proposed system depends on time, cost and complexity of the system. For this reason, most of the technologies used in developing the system were open source tools. Open source tool is a tool or software having its source code public accessible and therefore anyone can edit, modify and inspect (Ubwa, 2015).

3.2.7 Development Tools and Technologies

(i) Client-Side Languages

These are client-side scripting languages. The source code written with client-side languages is executed within the browsers. The source code execution process takes place within the end users' computers. Although the source code is executed within the browser, they are transferred from the web server to end users' computers through the internet.

Hyper Text Markup Language (HTML): HTML is used for formatting and displaying data. Referring to its name, HTML is a Markup Language which means it is basically used to mark-up text documents using tags which instruct a web browser how to structure and display the web page document. It is the most commonly used language to develop websites.

Extensible Markup Language (XML): XML is designed for storing and transporting data. It is a markup language in the similar way as HTML though Xml is specifically designed as data storage object. The tags in XML are not predefined while HTML uses predefined tags such as <html>, <body>, <form>, and <h1>. The proposed system interfaces on the mobile application part has been developed using XML language. The android uses XML for designing the layouts due to its lightweight.

Cascading Style Sheet (CSS): It is the language used to define the style presenting a web document written from a markup language such as HTML. It describes how HTML documents have to be presented or displayed. The study employed CSS to format most of the web pages' elements including colors, layouts and font's size and styles.

Bootstrap: This is an open-source framework technology used for developing web applications. It consists of HTML and CSS form templates, buttons, navigation, JavaScript extensions and other interface design components. The original name of Bootstrap is Twitter Blueprint since it was introduced by Twitter developers' team to mitigate the inconsistencies

and high maintenance burden experienced from various libraries which were used for interface development before the introduction of Bootstrap.

JavaScript: A JavaScript is an object-oriented programming language usually used to provide interactive features of web pages within the web browsers. It is a dynamic scripting language that helps to develop a dynamically updating content, animate images, control multimedia and many more. JavaScript is integrated within and embedded in HTML. It provides higher capability to control a web page than HTML does. It is an independent platform thus JavaScript integrated within HTML executes on Windows, Ubuntu, Linux, Macintosh and other Netscape supported systems.

It should be noted that JavaScript just resembles Java, but not the same as Java. Java is more powerful and platform-independent programming language than JavaScript. Normally it is used to develop applet programs which run in Netscape. It is also capable of developing a stand-alone program. JavaScript enables HTML authors to have great control over Java applet systems. Moreover, Java runs on the server and the source code is transferred to the clients' computer for execution. On the other hand JavaScript is interpreted within the client browsers.

(ii) Server-side Languages

It is a web technology whereby users fulfil their requests by executing a source code direct from the web server in order to provide dynamic website pages. They are used to develop interactive web-sites which provide dynamic web contents from databases or other data stores to users and vice-versa. Currently, a lot of scripting languages exist for server-side, to mention few; Nodes.js, PHP, Ruby on Rails, Django, ASP.NET, and Java. Each has its strengths and weaknesses which makes difficulties for programmers to choose a right server-side language for developing a dynamic website projects (Crawford & Hussain, 2017).

In this study PHP with Laravel framework and Java were used in development of the proposed system solution. PHP is used in developing the dynamic web system contents while Java is used in developing dynamic android mobile application contents.

Hypertext Preprocessor (PHP): PHP is one among the mostly used server-side scripting language employed in web-based systems implementation. A number of web-based systems are using PHP and therefore easily to get support of its developers worldwide.

Table 5: Comparison of Server–Side Scripting Languages

Language	Creation Date	Popularity (%) of entire internet use
Nodes.js	May 27, 2009	0.24
Ruby on Rails	December 18, 2005	0.3
Django	July 21, 2005	0.1
PHP	June, 1995	11.7

Source: (Crawford & Hussain, 2017)

Java: Java came to be among the most popular high level programming language following its release, particularly in web-based and distributed systems (Taboada, Ramos, Expósito, Touriño & Doallo, 2013). The fast rising in Java interest for computing is mainly due to its important characteristics of portability and object orientation. It's portable in the sense that one Java programme can run in many operating systems, Personal Digital Assistant (PDA) and on mobile phones (Masovic, Saracevic, Kamberovic & Kudumovic, 2012). That is why the official language for Android systems development is Java because major parts of android have been written using Java and its APIs are intended to be called using Java.

Database Implementation: The system is developed using My Structured Query Language (MySQL) for the back-end data storage or database. MySQL is compatible with different operating systems (OS) platforms such as SCO OpenServer, SCO UnixWare, Symbian, eComStation, OpenBSD, AIX, IRIX, Microsoft Windows, OpenSolaris, Linux, HP-UX, FreeBSD, i5/OS, BSDi, Solaris, Sanos NetBSD, OS/2 Warp, Mac OS X, Tru64, SunOS, QNX and Novell NetWare (Ubwa, 2015). For this reason, MySQL became the choice in developing the systems' database with assurance that the system will run into different OS platforms.

3.2.8 Source Code Editors

A source code editor is program designed purposefully to edit and write the source-code of computer programs. It can be either a standalone program or application such as Notepad++ or inbuilt into an integrated development environment (IDE) like android studio editor. Source code editors are very important programming tools because the basic task of computer programmers is to write and edit code.

(i) Visual Studio Code

The source code editor employed in this study is a Visual Studio Code. It is a source code editor created by Microsoft for Windows, Linux and macOS. It provides the following supporting features: syntax highlighting, debugging, snippets, intelligent code completion, and code refactoring.

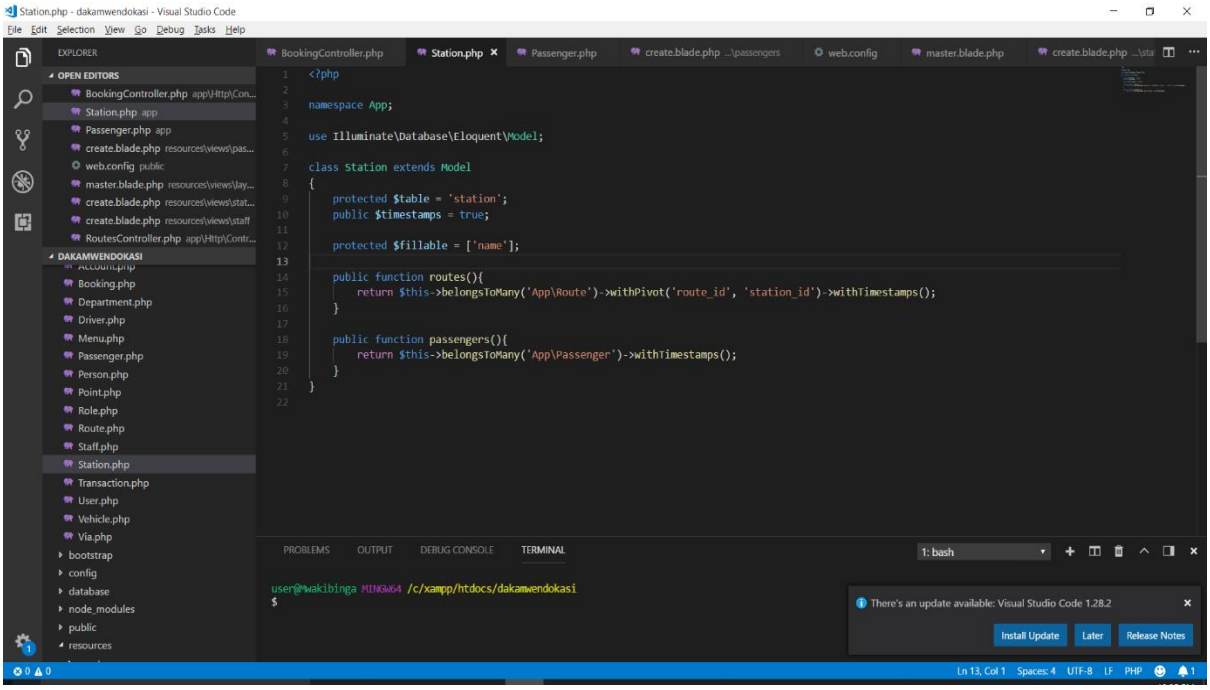

Figure 8: Screen Shot of Visual Studio Code

(ii) Android Studio Layout Editor

Android Studio contains an inbuilt and rich visual layout editor which enables programmers to develop better user interfaces for android applications. It is inbuilt feature within the android studio IDE. It avoids the need of deploying the APK onto a real device on every change, making the development process faster and helpful in eliminating common errors in the early stages of application development.

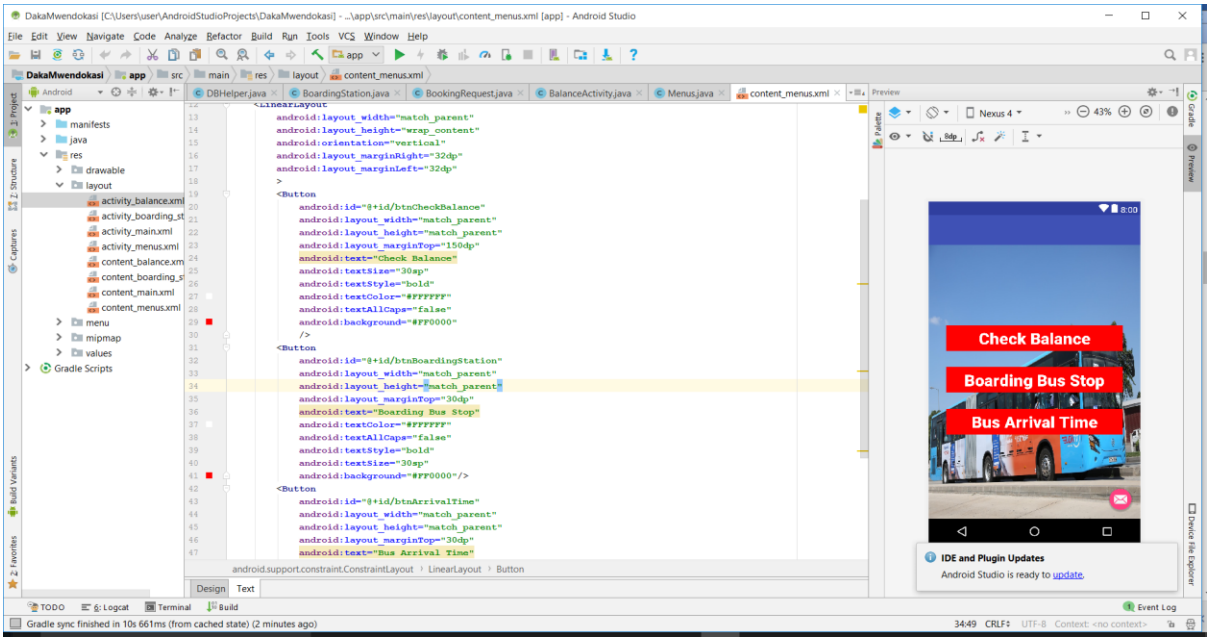

Figure 9: Screen shot for android layout editor

3.2.9 Other Requirements

(i) **Internet connection:** Both mobile application and web-based systems need internet connection to be accessible.

(ii) **Web browser:** Google Chrome, Mozilla Firefox, Torch and Internet Explorer.

(iii) **Operating system:** Web-based part of the system operates in Windows 7 and onwards versions, Mac OS and free Open Source Operating systems such as Ubuntu. Mobile application runs on android operating system only.

(iv) **Hardware:** Smartphones, tablets and personal computers.

3.2.10 Assumptions and Dependencies

(i) It is assumed that the passengers have access to a smartphone and UDART administration has installed LANs in their offices and stations.

(ii) Passengers have access and are able to pay charges for internet

(iii) The faultless of the system depends on the correct operation between PHP and MySQL with the web server in which the system runs.

(iv) Frequent availability of the system depends on the hosting webserver to be running most of the time without failure.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Case Study Area's Results and Discussion

The aim of this study was to identify the satisfaction levels of commuters to the services provided by UDART through BRT buses and develop a system to resolve challenges that passengers experience and also recommends measures to be taken for the improvement of the developed system for future better performance.

The study was limited to some areas of services which are ticket booking, pre-board waiting time and smart card's balance information. Passengers complain about the procedures they take to book their tickets that are tedious due to long queues especially during peak or rush hours. Except for main stations such as Kimara, Ubungo Terminal, Moroco, Gerezani and

Figure 10: Ticketing Booking at Kimara Terminal

Kivukoni which have more than two windows for booking tickets or toping up balance on smart cards, other stations have either one or two windows for selling tickets. Also passengers complain about the waiting time they take to board buses. Due to lack of real time transit information, passengers waste a lot of time waiting for buses to take them to their destination.

Furthermore, the passengers face challenge on checking their remaining balance, especially for those using smart cards. In order to check balance, one has either to go direct to the ticket booking office or scan the card at entry point/gate until one's card fails due to insufficient balance. During the scanning process, there is no notification of the balance in the card.

4.1.1 Respondents' Demographic Information

Overall 181 responses out of 250 were collected where by 91 (54.1%) were males and 82 (45.9%) were females. The gender balance was an important concern in selecting the sample. To meet this gender balance, the researcher was challenged by the number of female staff at DUCE and DSTV where their number was lower as compared to their male counterparts. However, efforts were taken to interview at least many female staff so as to meet the gender balance.

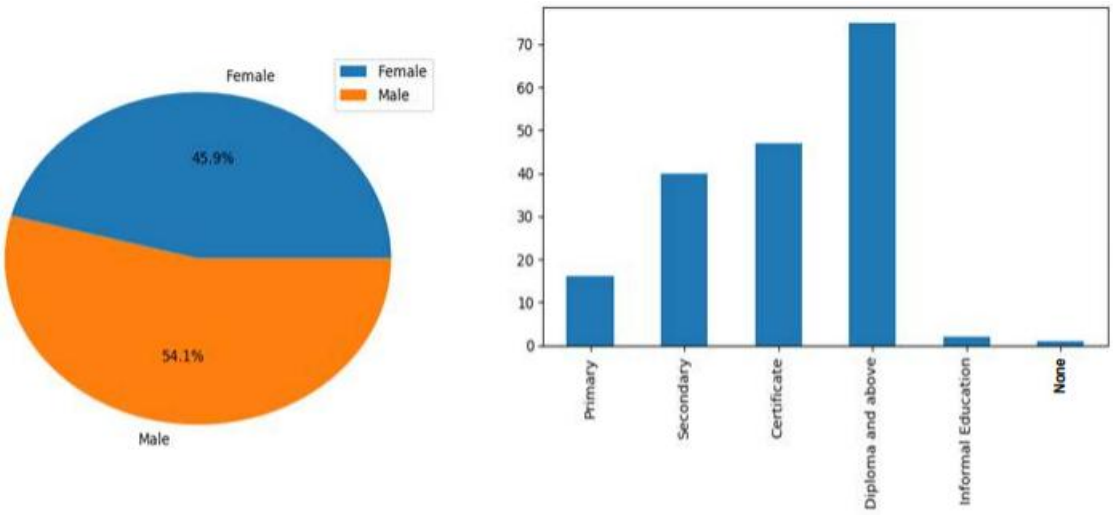

Figure 11: Respondents' Demographic Information

Moreover, the researcher sampled the respondents basing on their education levels such as primary, secondary, diploma and above. The results were as follows; 16 respondents have primary education, 40 have secondary education, 47 have certificate, 75 have diploma and above and 2 respondents have informal education. One response did not provide demographic information concerning education level.

4.1.2 Residents' Experience on Commuting with BRT

The aim was to determine whether the respondent has awareness on the BRT buses and their frequencies on travelling by BRT buses. The survey shows that 91.2% of respondents have been using BRT service.

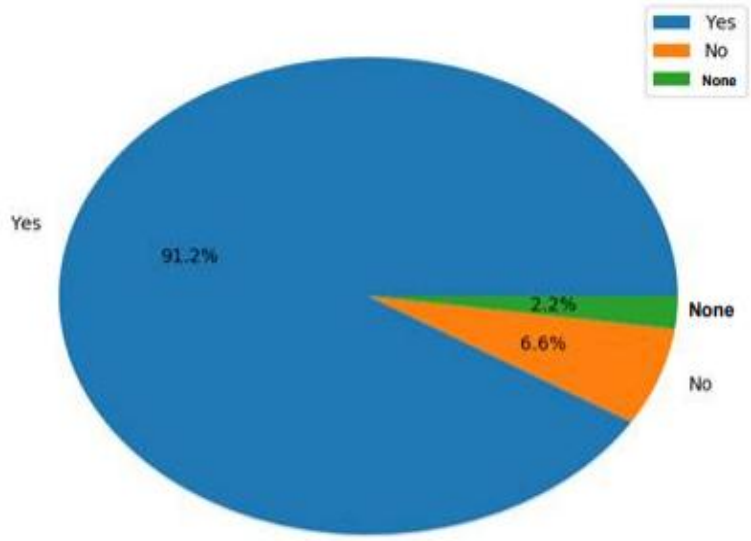

Figure 12: Residents' Experience on Commuting with BRT Buses

Only 6.6% of respondents claim to have never travelled with BRT buses while 2.2% did not provided information. It was further revealed that 39.1% of those who commute with BRT are using the service daily, 24.3% use in no longer than a week, 9.5% fortnightly, 7.7% in no longer than a month and 18.9% use the service less frequently.

As shown in Fig. 12 above, the number of city residents who are commuting with BRT buses is relatively high. Only 6.6% said have never commuted with BRT buses, and the reason may be either use their private cars or they reside in places where no BRT route has been built.

4.1.3 Passengers' Satisfaction Level over Paper-Based Tickets

The aim was to assess the satisfaction of the passengers to continue using paper-based tickets. The findings shows that 44.7% strongly agreed and 45.3% agreed that paper tickets contribute to littering and queuing during ticket booking on every trip. 9.4% of passengers disagree and 0.6% strongly disagree that paper tickets bring negative impacts to the passengers. Other concerns given by passengers from their experience in paper-based ticket are time consuming due to long queue and are easily destroyed.

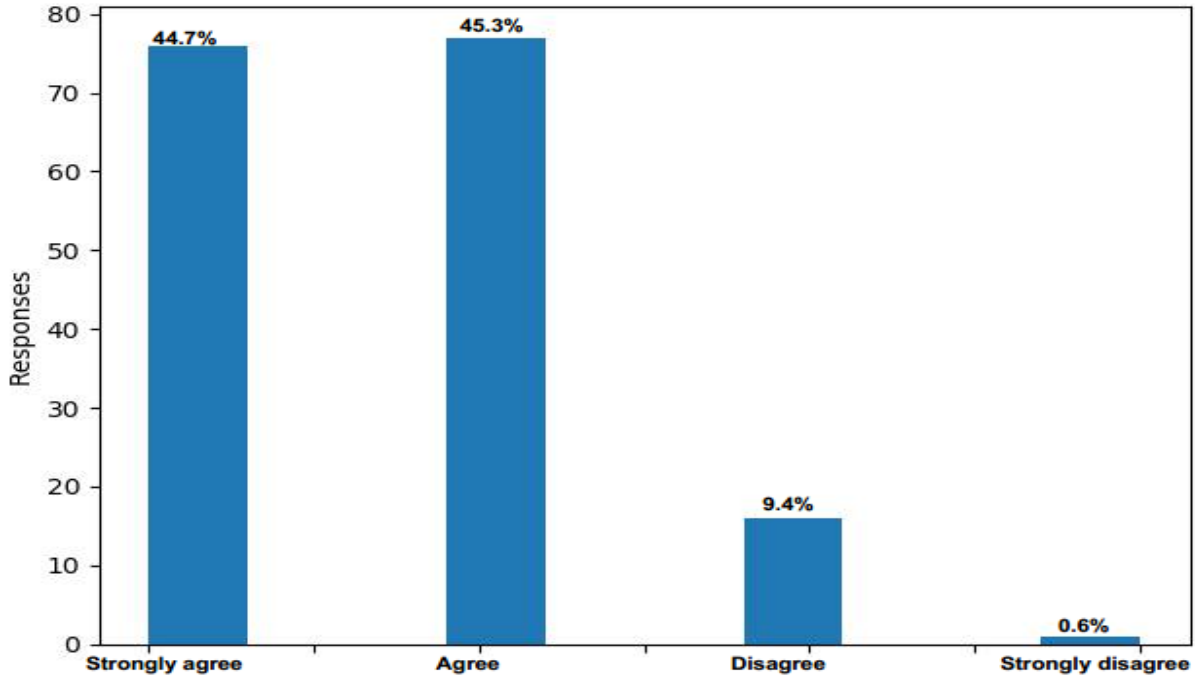

Figure 13: Satisfaction Level over Paper Tickets

4.1.4 Passengers' Satisfaction Level over Process to Check and Top-up Card balance

The study shows that 7.8% strongly satisfied, 20.6% satisfied, 35.3% dissatisfied and 36.3% strongly dissatisfied with the current means of checking their remaining balances. Generally, 71.6% of respondents are not satisfied with the procedures or means of checking their balance.

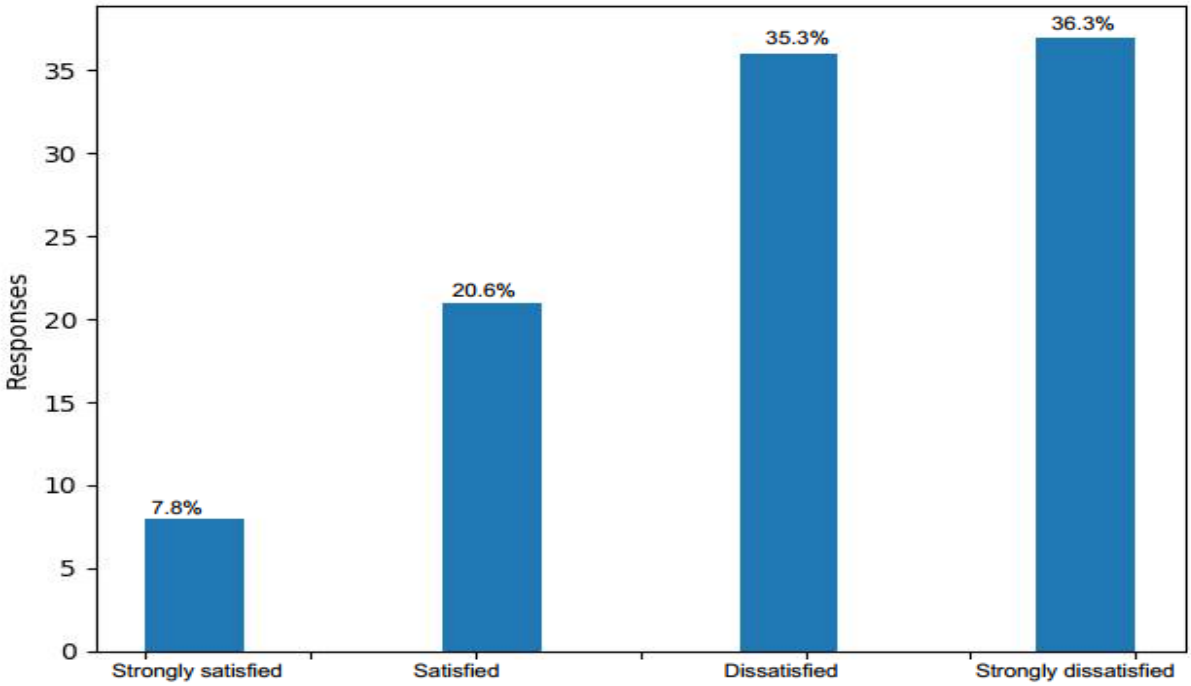

Figure 14: Satisfaction Level of Passengers over the Process to Check balance

4.1.5 Passengers' Satisfaction Level over the Bus Waiting Time

The study intended to identify the satisfaction level of passengers on the amount of time spent to wait bus at a particular station and their ability to predict the buses' arrival time to their boarding station and destination. The findings show that 7.1% strongly satisfied with the waiting time they spent at any particular station and 29.6% are satisfied while 39.6% are dissatisfied and 23.7% are strongly dissatisfied. Therefore, 63.3% are dissatisfied with the pre-board waiting time.

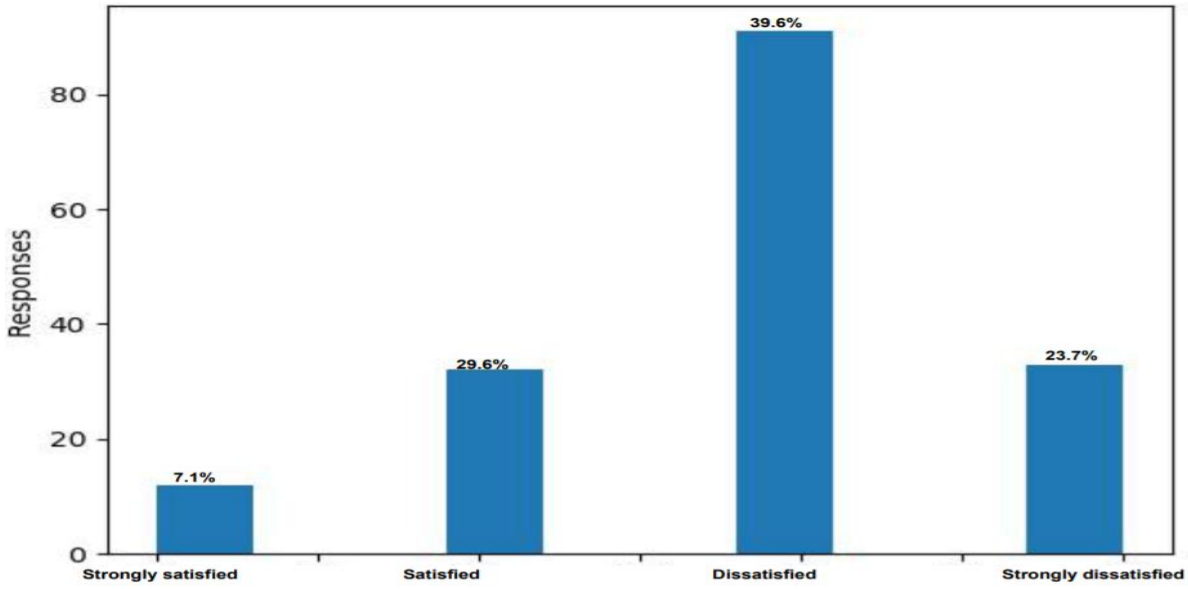

Figure 15: Satisfaction Level of Passengers to the waiting Time of BRT Buses

4.1.6 Passengers' Willingness to Develop the Proposed System

The survey also meant to assess the passengers' willing to use new technology that may helpful to check balance and receive the real time bus transit information in all routes using mobile phone application. Also, the findings show that, 53.9% strongly agree and 39.6% agree to develop a proposed solution. But also 4.5% disagree and 1.9% strongly disagrees to develop new proposed technology. Therefore, the study finds that about 93.5% of passengers they agreed to develop the technology that can help to address the observed challenges.

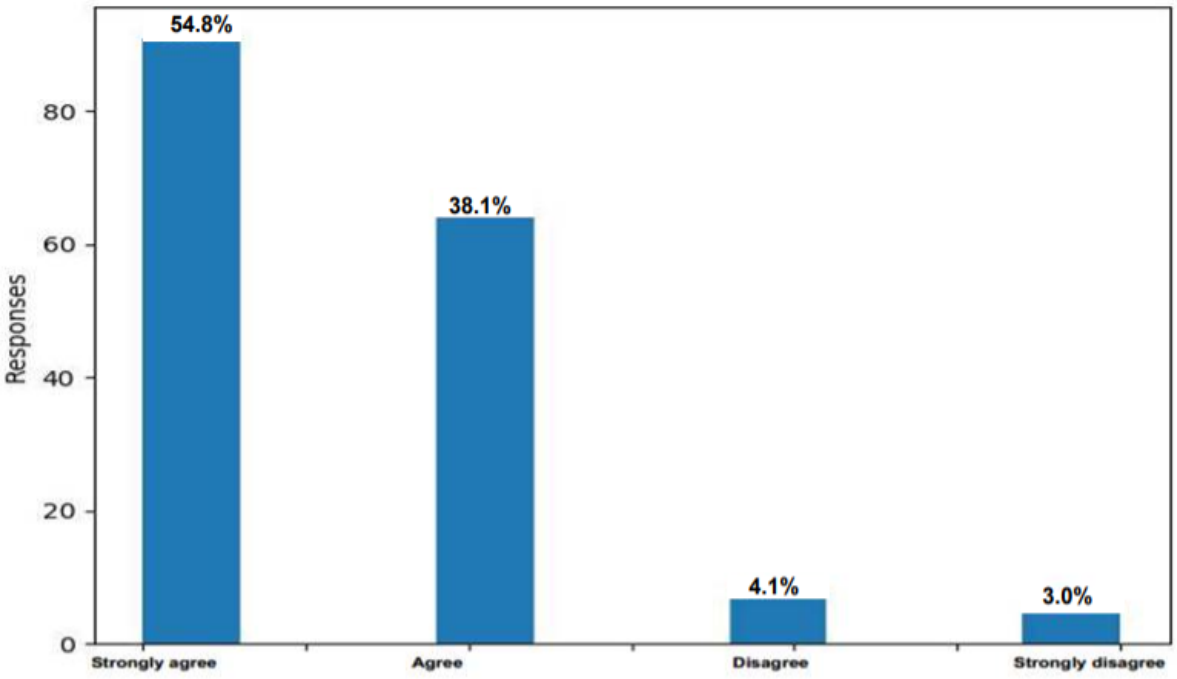

Figure 16: Passengers' Willingness to Develop Proposed System

4.2 Results and Discussion for the Developed Systems

The primary purpose of the results and discussion in this section is to interpret and report the worth of the research findings in light of what was already known or existing about the passengers' experience from commuting with BRT buses and therefore to enlighten new acumens, knowledge or technology to the problem after taking the findings into consideration**.**

4.2.1 The Mobile Application

The mobile application namely "Daka Mwendokasi" is based on android and therefore integrates the easiness and advantages that android system has to offer. The reason to implement the application using android is based on its market share as it is higher to others such as Symbian, iPhone etc. Therefore, developing the mobile application on the android platform also guarantees the maximum customer reach.

Presently the passengers of BRT buses in Dar Es salaam faces a lot of challenges such as long waiting queues to avail the paper-based tickets, unreliable bus arrival time, inability to check balance for those who own electronic smart cards and inability to forecast bus arrival time at specific station. The proposed system with mobile application as part of the system

enables passengers to check balance, forecast bus arrival time and send request to board a bus at any particular station. The following are features available in the proposed system.

(i) Login

The passengers have to login into the system using a smart card number that is available to every card and is unique. The passenger has to enter a valid card number otherwise he/she will receive a notification of failure to enter into the system. Figure 17 shows a screen shot for login activity

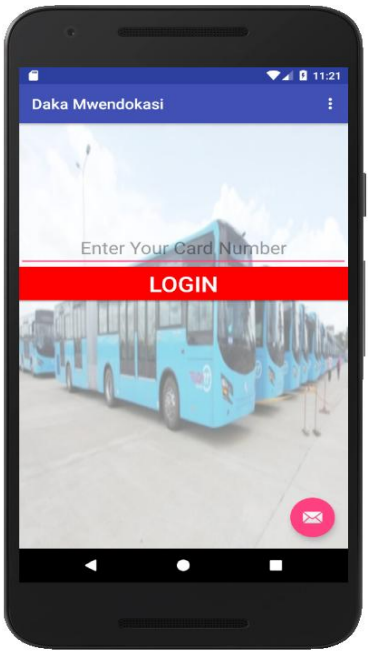

Figure 17: Login Interface for Mobile Application

(ii) Main Menu

The main menu represents the principal list of options or functionalities available to the user. The functionalities available in the developed system include; check balance, boarding station and bus arrival time. Only passengers with valid smart card number can get into the main menu. In other words, the main menu is the succession of login stage from valid users of the system only.

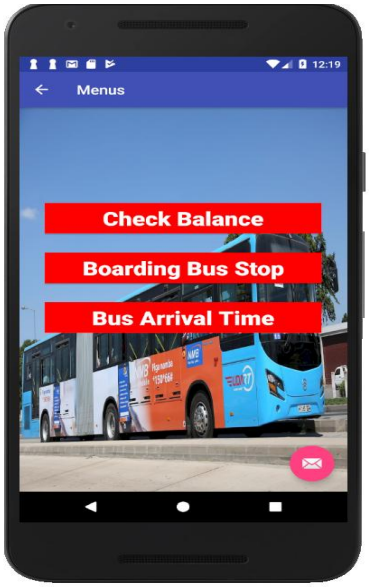

Figure 18: Mobile Application Main Menu

(iii) Check Balance

It enables a passenger to access and check balance from the central server. The system provides balance information based on the card number used to login. Each user or passenger is able to check his or her own balance only. The Fig. 19 below indicates three screen shots or android activities having different values of balances from different passengers.

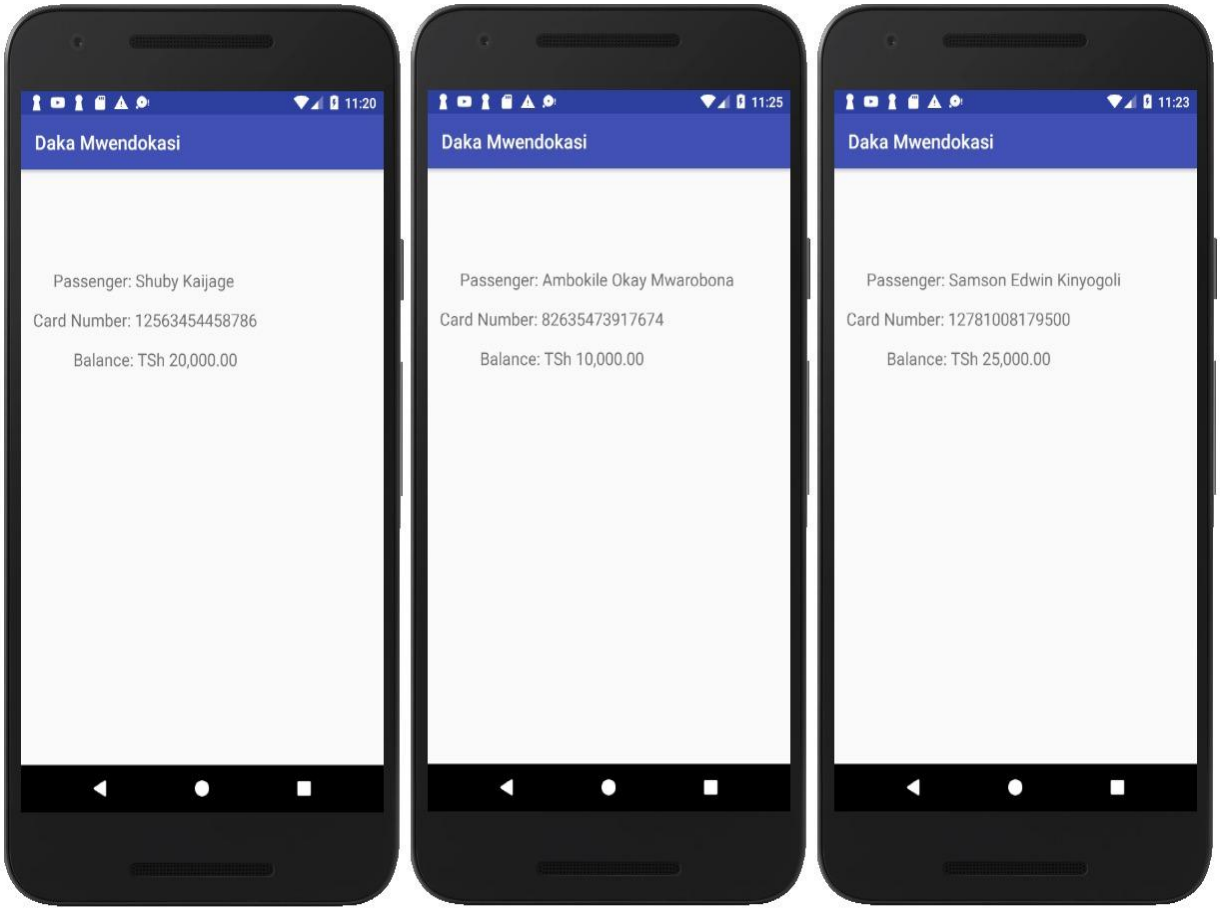

Figure 19: Passengers' Account Details Showing Name, Card Number and Balance

Presently, the activity for provision of balance information shows passenger's name, smart card number and balance. But it can be easily modified to include other details such as contact details when seemingly to be of necessary.

(iv) Boarding Bus Stop

Currently the UDART has no a sophisticated means of identifying the stations and routes with high number of passengers in order to best allocate buses in needy routes at a given time. This feature enables the passenger to send a request specifying the bus stop at which he or she expects to board a bus. The number of requests made from each station are counted, presented on web page and therefore easy to decide how best to allocate buses into different routes based on the number of passenger's request made from each station.

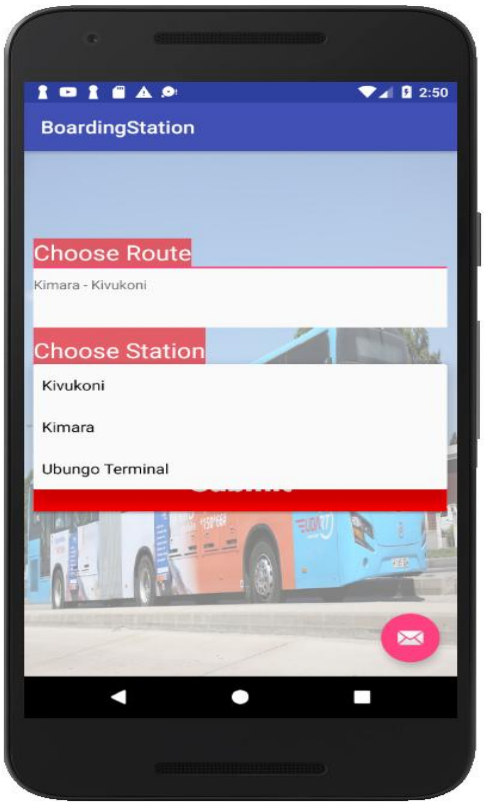

Figure 20: Interface for Selection of Route and Station

4.2.2 The Web-Based System

Web-based systems are developed primarily in order to be accessible through the browsers. The source codes and database files are located in a centralized server rather than being installed on the desktop system and is accessed over an internet. It differs from mobile application which has to be installed on the passenger's smart phone and communicate with the centralized database through internet. In other words, with mobile application there is no need of browser to access the central database.

The web-based system of the proposed system has functionalities such as staff registration, department registration, manage vehicle, bus driver assignment, passenger registration, station registration, and route registration and add user. The privileged users of the system are data entry and database administrator. The database administrator is able to add or reduce the number of functionalities to be accessed by the data entry.

(i) Registration of Staff

The system allows the registration of staff members of UDART Company. The registration process takes place on an easy-to-use web page as the registrar confirm the correctness of the

registered data by viewing on the right pane of web page. If the record is incorrect, there is a possibility of rectifying by using a drop-down button labeled “Action” where one can edit the incorrect filled record. A staff detail that may be recorded includes First Name, Middle Name, Last Name, Gender, Staff ID and Department unit.

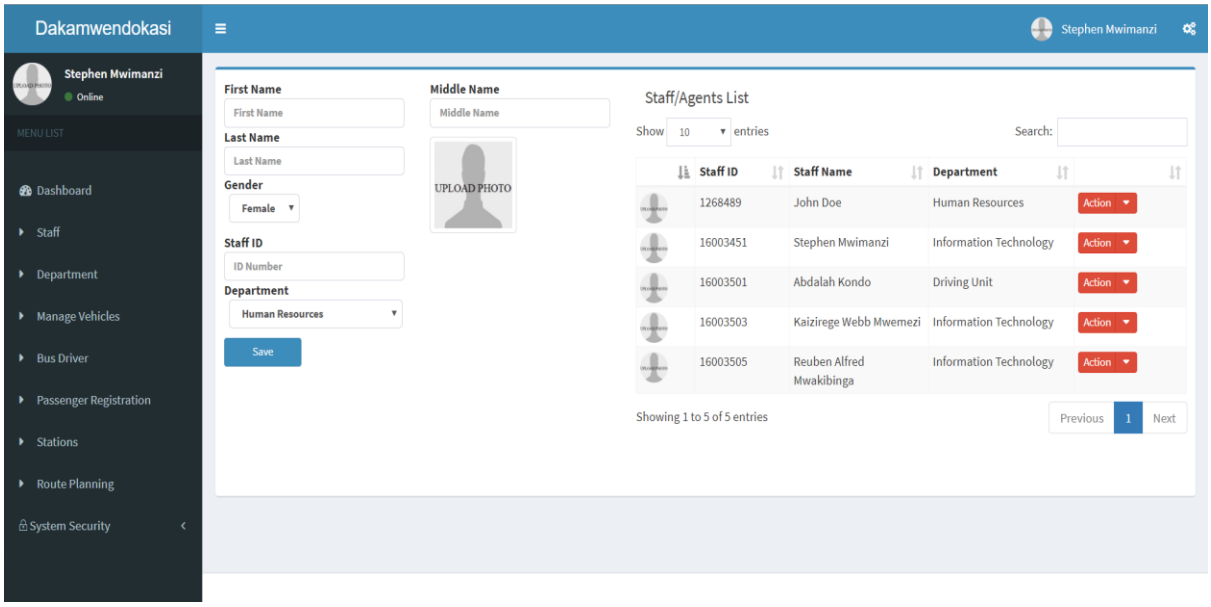

Figure 21: Staff Registration Page

Other important features to improve usability are search field and filtration field that filter number of records to be displayed on a particular web-page.

(ii) Vehicle Management

The vehicle management is a feature which allows the registration of vehicles into the system. The vehicles’ details recorded are plate number, number of passengers, and service type (Express or Normal). The filtration and search field are available for improved usability of the system.

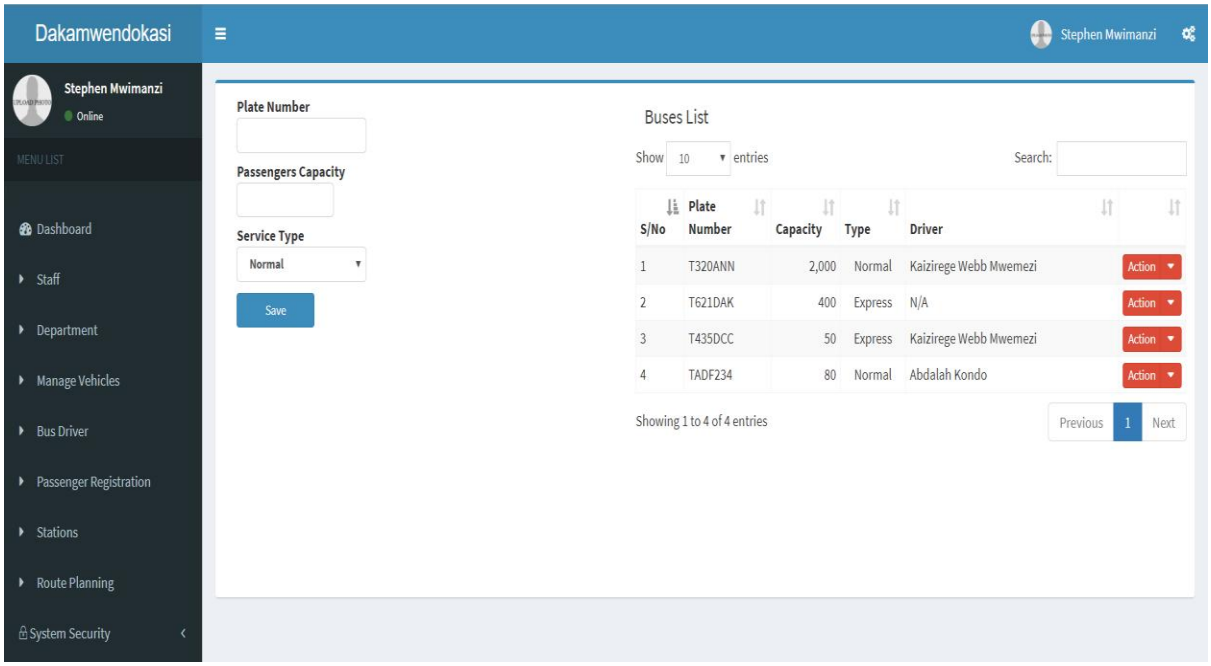

Figure 22: Vehicle Registration

(iii) Assignment of Bus Driver

This is a feature or functionality that helps to keep record of drivers being assigned a bus on a particular day. The details saved are plate numbers or bus number and drivers' names. But plate numbers of vehicles were added during vehicle registration process and drivers' names were also added during staff registration process. Consequently, the system generates the details from database using drop down field rather than re-typing the same data that appear in the database. After saving the record, the right pane of web-page will be display serial number (S/No) of the record, plate number of the bus, Type of service offered by bus (Normal or Express), Driver's name and Date of bus assignment.

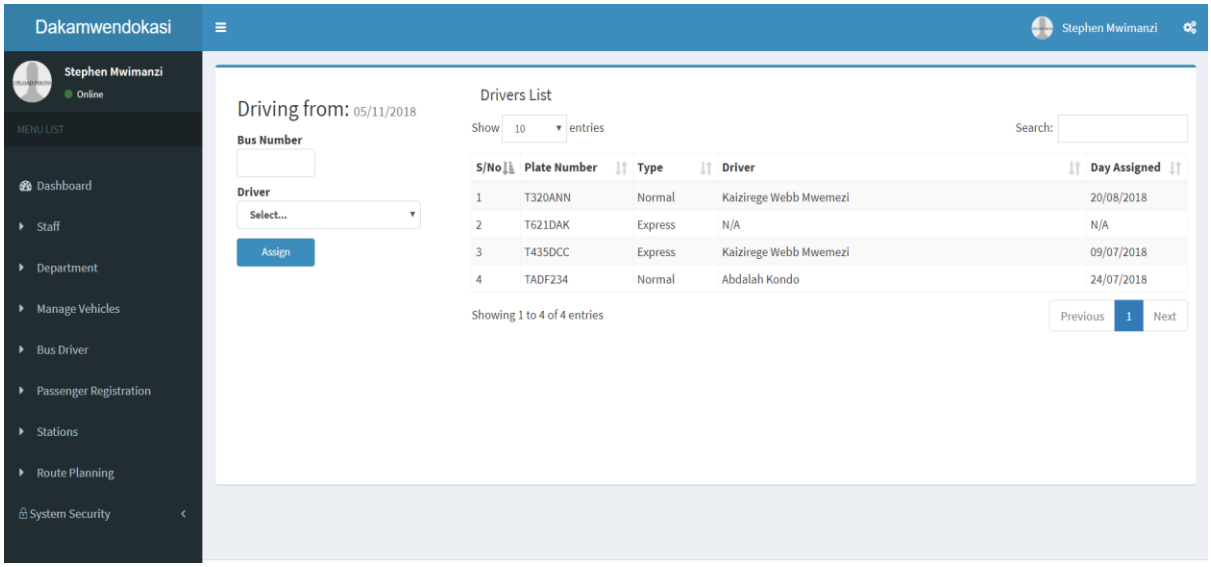

Figure 23: Driver Assignment

(iv) Passengers' Registration

The introduction of smart cards was to make the payment easier and faster. Also, the smart cards were expected to avoid scrambling for tickets from a single window at bus stations. But it was observed that out of 200 000 cards sold by UDART, only 50 000 were in use. About 150 000 passengers who own smart cards are not using them.

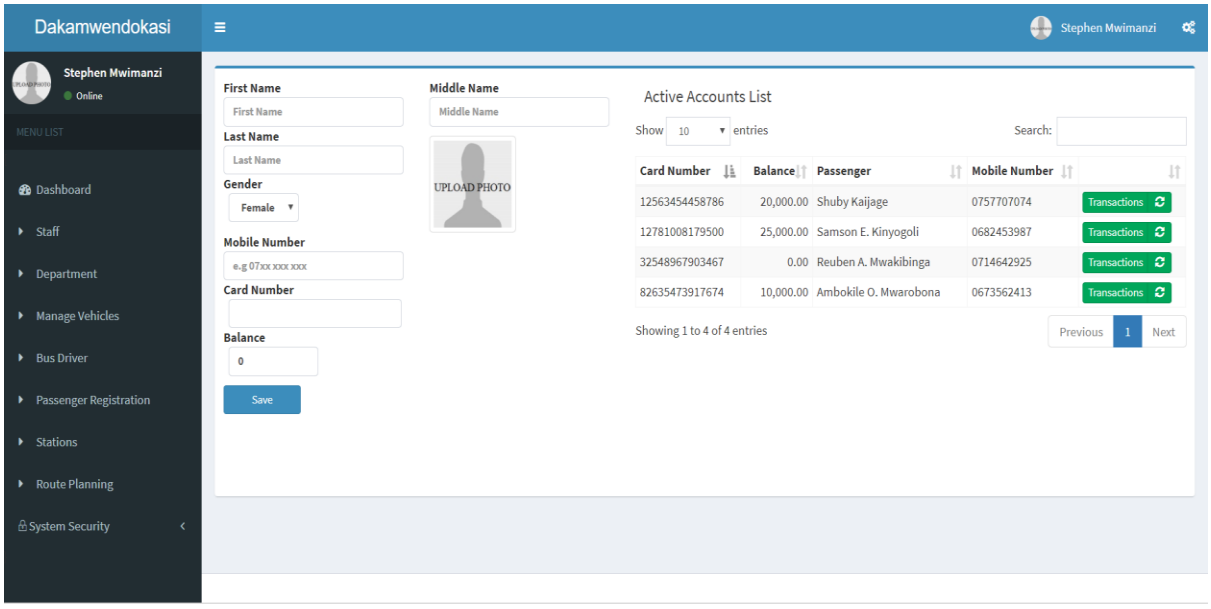

Figure 24: Passenger Registration Form

The reasons to why many passengers continue to use paper tickets regardless of having smart cards were observed. These included, after toping up balance, passengers were not able to confirm their balances from smart card account. Moreover, the passengers' details were not

mapped into the smart card. The proposed system will be helpful in resolving these challenges whereby a passenger will be able to check his balance using a mobile phone. Additionally, the passenger's details such as name and contact are mapped together with smart card number and stored into the database. This will help passengers to report the case to the police when the smart card gets lost. Figure 24 is a web-page showing details of passengers that are recorded during registration process. These include first name, middle name, last name, gender, mobile number, balance, and card number.

4.3 Validation

Validation test refers to the assessment of software throughout the development process or at the end of development process to find out if it gratifies the specified user requirements. Validation test guarantees that the product truly meets the user's needs. The validation testing of the proposed system passed through various steps of software testing which are unit test, integration test, system test, acceptance test and regression test.

4.3.1 Unit Test

Unit test is code-based software testing that is done by developers. It is mainly performed to test every individual functional unit distinctly. The unit testing of the proposed system was done in all individual functional units of the system such as login, check balance, passenger registration, vehicle registration, driver assignment, select boarding station etc. The unit testing stage is only done by developers because it involves inspecting of source code (Nidhra, 2012).

4.3.2 Integration Test

Integration test involves validation of two or more combined functional units of the system that are integrated to work together properly (Nidhra, 2012). Several functional units or groups of working units were integrated and tested to determine if they are properly working. Login from either mobile application or web-based system was designed as an entry point to main menus of the systems. Main menus and login are two independent functional units. But they are supposed to work together in a way that one cannot get to the home page before logging into the system. Integration testing has conducted to ensure a successful login takes a user at home page. Another integration testing conducted in this proposed system is to ensure that communication or data exchange between mobile and web-based system is properly working.

4.3.3 System Test

System test is done on a complete integrated system to determine if the developed system met its specified requirements or not. System testing is a result of all integrated components that have successful passed integration testing step. It does not deal with structural features of source codes but the functional features which are visible to end user (Nidhra, 2012). The system has passed all integration tests done while running on local server. The information submitted into the database from web-based system could be successful retrieved by mobile application and vice-versa.

4.3.4 User Acceptance Test

Acceptance test is conducted by anticipated users or customers of the developed software. The aim of acceptance testing is to determine whether the software is working properly and meets their core business requirements. Privileged users are allowed to interact with the system functional units to assess their correctness and other performance factors like speed, easiness and responsiveness (Nidhra, 2012).

Many respondents accepted the system and advised that the system should be deployed into actual environments as it will impress many BRT passengers to adopt smart cards which will discourage the mass consumption of paper tickets and thus keeping environment clean. On the other hand, the system was brought to UDART IT department for testing the web-based part of the system. The IT team accepted the system with some few inputs for improvements such as use of passwords to login into mobile application instead of card number because the card numbers have been printed on smart cards hence can be easily accessible to unauthorized individuals.

Moreover, questionnaires were distributed to different people with the aim of finding out users' perception and views on the developed system for reduction of passengers' observed challenges in commuting with BRT buses. The system summary test report is presented in Appendix 3.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The trend of traffic volume globally is well known; the traffic volume is rising and the demand of mobility is also increasing. Eventually, congested cities most from developing countries lose their attractiveness mainly due to queues, noise, and air pollution. The existing physical traffic control facilities are no longer the only justifiable solutions. Transport practitioners in developing countries should recognize that the current and future traffic problems in their growing and congested cities are also soluble through the use of intelligent integrated transportation systems. Therefore, this study has laid groundwork towards the improvement of public transport systems by using information technologies facilities that may best fit our environment. Customization of existing systems may results into unexpected running costs. The effective use of technology in public transport can minimize the traffic problems while using the same existing physical infrastructure such as roads and traffic lights. The provision of real time pre-board transit information may avoid congestion of passengers into bus stops.

Regardless of the observed challenges facing BRT passengers such as over-crowding within buses and at stations, long queuing during ticket booking and difficulties in checking their balances and inability to get real time transit information yet many people in Dar Es Salaam prefer to commute with BRT buses. The study found that majority of city dwellers in Dar Es Salaam are aware of the BRT buses' service and more than 90% of responses claimed to have commuted with BRT buses. This great demand of BRT services signifies the need to mitigate the observed challenges so as to improve the overall operation of BRT buses. These findings are important because they will help the UDART and the government at large, to address these challenges in order to impress many city dwellers to commute with BRT buses.

The proposed software enables the passengers with accounts to use a mobile application to interact with the central database while other side of the system allows UDART staffs to interact with the same database through web-based system. Generally, the developed integrated mobile and web-based system for passengers commuting with BRT buses is expected to provides the following; ability of passengers to check card balance, send request

to board a bus at a particular station, improve UDART's means of keeping and managing their records, and mapping card information to only one users.

5.2 Recommendations

The number of BRT buses operating in Dar Es Salaam is about 140, which does not meet the citizens' mobility demand in the first phase of the project. This has resulted into a long pre-board waiting time for passengers and an undesirable scramble to avail a chance in buses a character which does not favor the elders and the disabled ones. It is significant to take appropriate initiatives to meet the demand by adding more high capacity buses (carrying capacity of 150 passengers) from 140 buses which are currently in operation (Adam, 2018).

Moreover, it is necessary to add more electronic smart cards. The smart cards sold in the first batch were 200 000 cards. The proposed system once deployed, is expected to impress a good number of passengers to use smart cards, therefore the study advises that UDART should provide more smart cards to meet the demand which may rapidly increase. Switching many passengers to electronic smart cards may also help to reduce the paper tickets which seem to pollute environments (Adam, 2018).

Finally, the study welcomes other researchers to add features which could not be developed in the proposed system such as module to top-up balance using mobile money services (Tigo pesa, Airtel Money, M-pesa), real time transit information (bus location, bus speed and bus arrival time). The study suggests using API from UDART system to integrate data (bus location, bus speed and bus arrival time) into the proposed system rather than putting-in efforts to design new IoT infrastructures since these data are already available within the UDART system.

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APPENDICES

Appendix 1: Java Code for Processing the Main Menu of Mobile Application

```
package com.example.user.dakamwendokasi;
import android.content.Intent;
import android.os.Bundle;
import android.support.design.widget.FloatingActionButton;
import android.support.design.widget.Snackbar;
import android.support.v7.app.AppCompatActivity;
import android.support.v7.widget.Toolbar;
import android.view.View;
import android.widget.Button;

public class Menus extends AppCompatActivity{
   @Override
   protected void onCreate(Bundle savedInstanceState) {
      super.onCreate(savedInstanceState);
      setContentView(R.layout.activity_menus);
      Toolbar toolbar = (Toolbar) findViewById(R.id.toolbar);
      setSupportActionBar(toolbar);
      Button btn_check_balance = (Button) findViewById(R.id.btnCheckBalance);
      // btn_check_balance.setOnClickListener();
      Button btn_boarding_station = (Button) findViewById(R.id.btnBoardingStation);
      //btn_boarding_station.setOnClickListener(this);
      Button btn_arrival_time = (Button) findViewById(R.id.btnArrivalTime);
      Button btn_boarding = (Button)findViewById(R.id.btnBoardingStation);
      btn_boarding.setOnClickListener(new View.OnClickListener() {
         @Override
         public void onClick(View view) {
            Intent boardingIntent = new Intent(view.getContext(), BoardingStation.class);
            boardingIntent.putExtras(getIntent().getExtras());
            startActivity(boardingIntent);
         }
      });
      FloatingActionButton fab = (FloatingActionButton) findViewById(R.id.fab);
      fab.setOnClickListener(new View.OnClickListener() {
         @Override
         public void onClick(View view) {
            Snackbar.make(view, "Replace with your own action", Snackbar.LENGTH_LONG)
                  .setAction("Action", null).show();
         }
      });
      getSupportActionBar().setDisplayHomeAsUpEnabled(true);
      btn_check_balance.setOnClickListener(new View.OnClickListener(){
         @Override
         public void onClick(View view){
            Intent balanceIntent = new Intent(Menus.this, BalanceActivity.class);
            balanceIntent.putExtras(getIntent().getExtras());
            startActivity(balanceIntent);
```

Appendix 2: System Summary Report

SYSTEM SUMMARY TEST REPORT

AN INTEGRATED MOBILE AND WEB-BASED SYSTEM FOR BUS RAPID TRANSIT (BRT) IN DAR ES SALAAM

Version 1.0

08/11/2018

Introduction

1.1 Purpose

This Test Report for **Integrated Mobile and Web-based System** provides a summary of the results of test performed as outlined within this document.

1.2 Test Summary

System Name: Daka Mwendokasi

Version Number: 1.0

Additional Comments: The validation process conducted and completed successful throughout all steps needed for software testing. These are unit testing, integration testing, system testing and lastly user acceptance testing.

1.3 Test Type: Unit Testing

Tester and Owner: Reuben Alfred (Developer)

Test Date: 12/08/2018 – 30/10/2018

Test status: Pass

1.4 Test Type: Integration Testing

Tester 1: Reuben Alfred (Developer)

Tester 2: Kaizirege W. Mwemezi

Tester 3: Linus John

Test Date: 08/09/2018 – 30/10/2018

Test status: Pass

1.5 Test Type: System Testing

Tester 1: Reuben Alfred (Developer)

Tester 2: Dr. Shubi F. Kaijage (Developer & Supervisor)

Tester 3: Kaizirege W. Mwemezi

Tester 4: Linus John.

Test Date: 08/09/2018 – 30/10/2018

Test status: Pass

1.6 Test Type: Acceptance Testing

Tester: Passengers and UDART staff (IT department)

Test Date: 08/09/2018 – 30/09/2018

Test status: Pass with minor inputs

2.0 Test Results

The test was conducted to two groups of users, passengers on one side of developed system which is mobile application and UDART staff from IT department on the other side of system which is web-based. The test conducted from UDART have passed all steps of software testing, but with an input of considering using a password instead of card number since card number are exposed to everyone who may come across the card. For passengers, questionnaires were made and given to different people who had experience in commuting with BRT aiming at finding out users' perception and views on the developed system for reduction of passengers' observed challenges in commuting with BRT buses. The table below indicates the questionnaire test results from passengers.

	Strong agree (%)	Agree (%)	Disagree (%)	Not sure (%)
The application is easy to use	62	38	0	0
The web application will impress many passengers to use smart cards and get rid of paper tickets to conserve environment	45	50	0	10
The web application will help passengers to view their balance	72	27	0	1
The application interfaces are well organized and easily accessible with minimal assistance	75	20	1	4
This application will benefit UDART to best decide on allocation of buses to a needy route	60	40	0	0

Appendix 3: Questionnaire for Data Collection

Introduction:

My name is Reuben Alfred, pursuing Master's in Information and Communication Science and Engineering of The Nelson Mandela African Institution of Science and Technology (NM-AIST). I have completed coursework and therefore getting to other part of my study which is research. My research title is "**An Integrated Mobile and Web-Based System for Bus Rapid Transit (BRT) In Dar es Salaam**" This questionnaire aims at gathering requirement for the proposed system. Thank you for your willingness to participate in this exercise.

Section A: Demographic Information

1. What is your gender?

☐ Male ☐ Female

2. What is your education level?

☐ Primary ☐ Secondary ☐ Certificate ☐ Diploma and Above ☐ Informal Education

Section B: Awareness and experience on DART service

3. Have you ever been used UDART service?

☐ Yes ☐ No

4. Which route(s) do you regularly use? (Tick all that apply)

☐ Kimara - Gerezani ☐ Kimara – Kivukoni/Posta ☐ Kimara - Moroco ☐ Ubungo – Moroco ☐ Ubungo – Gerezani ☐ Ubungo – Kivukoni ☐ Mbezi – Kimara

5. What is your main reason for using the UDART service?

☐ Commute to work ☐ Getting to School ☐ Shopping ☐ Leisure/Social

☐ Medical ☐ Any other(state)……

6. How often do you use the service?

☐ Daily ☐ Weekly ☐ Fortnightly ☐ Monthly ☐ Less Frequently ☐ Never

Section C: Passengers' ticket booking Experience

7. How do you book/ collect a ticket or recharge a card for a journey? (Please tick the most appropriate)

☐ Through a friend or relative ☐ Face to Face with booking staff

☐ Other (Please state) ……

8. Overall, how satisfied are you with the service based on your choice in 7 above?

☐ Extremely satisfied ☐ Satisfied ☐ Dissatisfied ☐ Very dissatisfied

9. How helpful do you find the office and booking staff?

☐ Very Helpful ☐ Helpful ☐ Not helpful ☐ Very unhelpful

Section D: Passengers' perception based on paper-based tickets versus using electronic smart cards

10. Which ticket do you normally use?

☐ Paper based ticket ☐ Electronic smart card

11. Paper based ticket is said to bring challenges to customers and environment such as queuing every time a customer books ticket and littering.

☐ Strongly Agree ☐ Agree ☐ Disagree ☐ Strongly Disagree

12. List any other challenge(s) that you experience from using paper-based tickets

…….

…….

…….

…….

13. If you have also been used an electronic card instead of paper-based tickets, how are you able to know your remaining amount (balance)?

☐ Go direct to booking staff

☐ Use a card until stopped/rejected by machine due to insufficient balance

State any other(s)

……

……

14. Are you generally satisfied with methods you use as stated in 13 above to view your remaining balance (for those who have used electronic card)

☐ Extremely satisfied ☐ Satisfied ☐ Dissatisfied ☐ Very dissatisfied

Section E: Passengers' experience on time of travel and route information

15. Do you always board a bus which takes you to your intended destination?

☐ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree

16. Can you correctly predict bus arrival time to the destination?

☐ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree

17. Do you find the bus is punctual and gets you to your destination on time?

☐ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree

18. Are you satisfied with the time it takes from booking and/or arriving at station to boarding a bus?

☐ Extremely satisfied ☐ Satisfied ☐ Dissatisfied ☐ Very dissatisfied

19. If an online application may have developed to assist you to manage your account balance and other particulars and provides you bus real time transit information so as to have all

buses' information like current station, time to arrive at your boarding station, will it be convenient to you?

☐ Strongly agree ☐ Agree ☐ Disagree ☐ Strongly disagree

Section F: Passengers' experience on using Mobile phones and Internet

20. Do you possess a mobile phone?

☐ Yes ☐ No

21. What type of mobile phone do you own?

☐ Featured phone ☐ Smartphone

22. Do you have access to internet?

☐ Yes ☐ No

23. If yes in 22 above, which technology do you use to access internet most of the time?

☐ Smart phone ☐ Ipad ☐ Laptop/ Desk top computer

24. How frequent do you pay for mobile phone service charges?

☐ Daily ☐ Weekly ☐ Fortnightly ☐ Monthly ☐ Less Frequently ☐ Never

Information needed from UDART staff (Interview Questions)

1. When did UDART buses start operating?
2. The average number of passengers per day for each year since the start of service?
3. Is information about routes and passengers' balances digitally stored?
4. Do you have any strategies of making real time transit information available to passengers/ customers online?
5. Which ticketing system does many passengers prefers? Electronic smart cards or paper-based ticket
6. Would you like to have an online application to help passengers be able manage their accounts i.e being able to check their balances and get real time transit information using their mobile digital devices?